THE WHITE HOUSE
WASHINGTON

Date: 4-18-90

FOR: Gov. Sununu

FROM: ANDY CARD Andy

☒ Action ASAP

☐ Your Comment

☐ Let's Talk

☐ FYI

I recommend that you call and say the document is not a WH document.

JOHN KERRY
MASSACHUSETTS

United States Senate

WASHINGTON, DC 20510

April 18, 1990

The Honorable John Sununu
Chief of Staff
White House
1600 Pennsylvania Avenue
Washington, DC 20500

Dear John:

The attached document was delivered to me by an individual attending the White House conference on global warming.

Obviously, some of the document conforms with the President's comments yesterday. Some of it however, points out a strategy that seems very much at odds with the intent of the global warming conference, ie: to make real progress and develop policy options to resolve the issues associated with global warming. Certainly at first blush this paper presents a disturbing insight into the Administration's position on addressing global warming.

It is possible that this document does not in fact represent the Administration's approach to the issues under discussion at the conference. Perhaps the document is not itself a White House document at all. I have been told that a number of environmental organizations and several reporters at the conference will have this document and will soon be contacting several of us on the hill for comment, I would greatly appreciate it if you could telephone me on this matter as soon as it is possible to discuss its content.

Sincerely,

John F. Kerry
United States Senator

attachment.

DEBATES TO AVOID

* NOT BENEFICIAL TO DISCUSS WHETHER THERE IS OR IS NOT WARMING, OR HOW MUCH OR HOW LITTLE WARMING. IN THE EYES OF THE PUBLIC WE WILL LOSE THIS DEBATE. A BETTER APPROACH IS TO RAISE THE MANY UNCERTAINTIES THAT NEED TO BE BETTER UNDERSTOOD ON THIS ISSUE.

* DON'T GET INTO AN ADVOCACY POSITION OF THE MERITS OF VARIOUS POLICY PROPOSALS.

* DON'T LET REPORTERS POSITION THIS CONFERENCE AS AN ATTEMPT TO DELAY SERIOUS DECISIONS ON THIS ISSUE.

* THIS CONFERENCE IS ACCELERATING THE INTERNATIONAL DISCUSSION AND UNDERSTANDING OF THESE ISSUES. (DON'T USE SPECIFIC NUMBERS IE., DEGREES, DOLLARS, RATES ETC.)

TALKING POINTS
APRIL 17, 1990

* The U.S. is taking environmentally responsible actions that make sense on their own merits that also help deal with global change issues.

* The U.S. Conference is working in complement to the IPCC.

* The world community is making great strides towards understanding the science of global change, but many fundamental questions remain

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release April 18, 1990

FACT SHEET

UNITED STATES INITIATIVES ON GLOBAL CLIMATE CHANGE

During his first year in office, the President has advanced a large number of initiatives to enhance the quality of the environment. Several of these initiatives, when fully implemented, will result in substantial reductions in future greenhouse gas emissions in the United States -- at least 15 percent by 2000, and even more in later years. The measures are outlined below.

Full Phase-Out of Chloroflourocarbons (CFCs)

The President has committed the United States to a worldwide phaseout of the production and use of CFCs by the year 2000. As a further step, the President signed into law a unilateral U.S. fee on production of CFCs. This will reduce U.S. emissions of CFCs below levels allowed by international protocols.

Clean Air Act

The President's proposed revisions to the Clean Air Act call for two steps which will substantially reduce carbon dioxide emissions:

- A 10 million ton reduction of sulfur dioxide emissions from 1980 levels; and
- A cap on emissions at this sharply reduced level in perpetuity.

These measures in combination create a powerful incentive for energy conservation in the electric utility sector. The President's proposal on clean air would also increase the use of alternative fuels and includes measures to reduce carbon monoxide, nitrogen oxides, and volatile organic compounds. Both of these initiatives will result in substantial reductions of greenhouse gas emissions.

Reforestation

The President's fiscal year 1991 budget contains $175 million to fund the first year of a multi-year program to plant one billion trees a year across America. This program has the potential to sequester up to 5 percent of annual U.S. carbon dioxide emissions within 20 years.

Increased Funding for Solar and Renewable Energy and for Energy Conservation

The President's fiscal year 1991 budget contains about $360 million for research and development activities in solar and renewable energy and energy conservation. This represents a 75 percent increase over the amount requested in the previous year, and an increase of about 10 percent above fiscal year 1990 enacted levels. This research will be critical to identifying technologies which will allow us to meet our energy needs in environmentally efficient ways.

Energy Saving Appliance Standards

The Department of Energy recently issued new appliance standards which will result in increased energy conservation and reduced energy demand to service affected products. These standards are projected to reduce U.S. carbon dioxide emissions by up to one percent by the year 2000.

The White House Conference
on
Science and Economics Research Related to Global Change

REPORT ON FIRST DAY

April 17, 1990

THE OPENING OF THE CONFERENCE:

The White House Conference on Science and Economics Research Related to Global Change started with a successful and well received reception at the National Air and Space Museum on the evening of April 16, 1990. The highlight of the evening was the showing of several minutes of spectacular IMAX film of the planet, taken from the space shuttle, and narrated by the shuttle commander and photographer, Jim Weatherbee. A pre-conference luncheon for developing countries also added to the beginning of the Conference. The reaction of many delegates to these beginning events of the Conference seemed to be very positive, which set a constructive tone for the formal opening on Tuesday, April 17, 1990. Seventeen nations and the leadership of the E.C. and the OECD sent ministerial-level delegations to the Conference (a list of Delegates is attached along with the Conference Agenda).

SUMMARY OF THE FIRST DAY'S ACTIVITIES

The Conference was initiated with a welcome by Secretary Brady. President Bush then formally opened the Conference and welcomed the delegates with an address that was well received by the visiting delegates. A number of delegations commented on the commitment of the President and his administration to the issues of Global Change, and on the importance of the ideas outlined in his opening remarks, which set an important tone for the Conference. The goals and expectations of the Conference were outlined by D. Allan Bromley, on behalf of the Conference Co-Chairmen, which was followed by a few remarks by the head of the Polish delegation, a Deputy Prime Minister (Speech enclosed). The substantive issues being raised by the Conference were developed in three Theme addresses by the three Conference Co-Chairmen, Michael J. Boskin, D. Allan Bromley, and Michael R. Deland.

A luncheon address by William Reilly was very well received, in which he addressed the important issues of international cooperation in the science and economics research of Global Change and outlined a comprehensive action plan for addressing the policy issues of Global Change

The afternoon sessions of the Conference were devoted to Working Group discussions, focussing primarily on the first two themes of the Conference, the research challenges of Global Changes and strategies for and challenges to integrating economics and science research. The sessions were chaired by visiting delegates, mostly the heads of country delegations, who each gave

short introductory remarks. The science and economics of Global Change were addressed in well received presentations by U.S. scientists and economists. These opening presentations set a positive tone which lead to constructive dialogue. The U.S. offered two of its four proposals, both of which were well received (the other two proposals are scheduled to for introduction during the first session on Wednesday, April 18 - all four proposals are enclosed). The Working Group sessions appeared to be very well received by the delegates providing an opportunity for discussions by many delegates on the substantive topics of the Conference.

The expectations of visiting delegations, on arrival, appeared to range from a complete understanding of the U.S. goals and expectations for the Conference to suggestions that the agenda be altered to provide more opportunity to address policy related Global Change issues. The combination of an opening plenary session, a focussed address during lunch, and Working Group sessions for the full afternoon seems to have set a very constructive and positive tone for the whole Conference. The formal Conference meetings for the day appeared to end with high expectations for continued and constructive discussions during the Wednesday Working Group sessions. Two of the Conference goals, that of adding a integrating focus for international thought on Global Change, the concept of "Global Stewardship", and the introduction of a new dimension to the international dialogue on Global Change -- the proposition that economics, both analysis and research on broad economic policy and on economic consequences of policy options, is an essential link between the science of Global Change and policy alternatives, are being well received and are contributing to good discussions.

FILE= WHC_REPT.417

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NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
P.O. Box 3000 • Boulder, Colorado 80307-3000
Telephone: (303) 497-1000 • Telex: 989764

12 April 1990

Dr. John H. Sununu
Chief of Staff
White House
Washington, DC 20500

Dear John:

I enjoyed meeting with you, Allan Bromley, and Dan Albritton on 30 March. I hope we are making progress in answering your questions about climate models. Your comments are well taken on the need for adequate vertical, as well as horizontal, resolution in climate models.

If I recall correctly, you wanted to know what happens, in terms of slowing down greenhouse warming, when we increase the depth of the upper ocean (where most of the additional heat goes). The atmospheric radiative forcing part of the model allows for solar and infrared radiation with clouds (Kiehl et al., 1987). Solar radiation is generally broken down into two regions—one is between 0–0.9 μm and is usually denoted ultraviolet and visible; the other is 0.9–4.0 μm and is denoted near-infrared. In the present calculation, we make this division into 0.0–0.9 μm and 0.9–4.0 μm intervals. The model includes fractional clouds, absorption by gases in the ultraviolet, absorption by ozone in the visible spectral regions, carbon dioxide, water vapor, oxygen, cloud-level liquid water, and albedos (that is, reflectance of clouds and the surface).

After averaging out horizontal effects, we set forth the basic physics of the climate model (see enclosed reprint by Dickinson, 1981), where steady-state global temperature change ΔT, due to a change in external heating ΔQ in the climate system, gives

$$\Delta T = \frac{\Delta Q}{\lambda}, \tag{1}$$

where λ is the feedback describing the change of outgoing thermal and reflected solar radiation at the top of the atmosphere. If λ is large, then the temperature change is small and vice versa. Various National Academy studies estimate that (approximately) $\lambda \simeq 2$ W m^{-2} K^{-1}.

In time-dependent form, (1) becomes

$$C\frac{\partial T}{\partial t} + \lambda T = \Delta Q, \tag{2}$$

where C is the heat capacity of atmosphere-ocean climate system. Because the climate system has several sub-systems, such as the atmosphere and the oceans with different heat capacities, it is better to separate them into two equations for each medium, that is,

$$C_a \frac{\partial T_a}{\partial t} + \lambda_{am}(T_a - T_m) + \lambda T_a = \Delta Q, \tag{3}$$

$$C_m \frac{\partial T_m}{\partial t} + \lambda(T_m - T_a) = 0, \tag{4}$$

where T_a and T_m are atmospheric temperature and ocean mixed-layer temperature; C_a and C_m are heat capacities of the atmosphere and ocean mixed layer; λ_{am} is the feedback parameter between the atmosphere and ocean mixed layer (estimated $\simeq$ 50 W m^{-2} K^{-1}). The latter term allows transfer of heat for the atmosphere and ocean. The following table provides quantitative measures of the parameters:

Medium	Mass ($\times 10^3$ Kg m^{-2})	Heat Capacity (W m^{-2} year K^{-1})
Atmosphere	14	$C_a = 0.45$
Ocean mixed layer (81 m)	81	$C_m = 10$

The solution to (3) and (4) can be simplified by combining the two first-order ordinary differential equations into one second-order ordinary differential equation that can be solved by a simple Runge-Kutta numerical method incorporated into the computer program.

In determining climate change in this simple model, we first estimated λ from a radiative column model by using, say, a vertical profile of tropical atmospheric temperature. The climate sensitivity factor is obtained from variations of the net radiative flux at the tropopause due to changes in temperature and moisture. Thus,

$$\lambda = \frac{dF^N}{dT} = \frac{\partial F}{\partial T} + \frac{\partial F}{\partial q}\frac{dq}{dT} + \frac{\partial S}{\partial q}\frac{dq}{dT}. \tag{5}$$

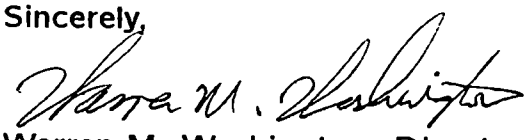
The quantities $\partial F/\partial T$, $\partial F/\partial q$, and $\partial S/\partial q$ are obtained from the column radiation model. dq/dT is estimated from the assumption of fixed relative humidity. Calculations from the column model yield a value of $\lambda \simeq 2$ W m^{-2} K^{-1}. Once λ has been determined, it can be used in (4) to obtain a change in the ocean mixed-layer temperature for a given forcing ΔQ. For example, a doubling of carbon dioxide yields $\Delta Q \simeq 4$ W m^{-2}. Thus, from (1) the equilibrium temperature change would be expected to be $\Delta T \simeq 2$°K.

The time-dependent evolution of ΔT can be obtained from the computer model of the mixed-layer temperature change described above. The column radiation model can also be used to calculate ΔQ for other carbon-dioxide concentrations. A note of caution, however—Figures 2.12 and 2.13 (enclosed) show that the upper mixed layer of the ocean is approximately 70 m or so. Our knowledge of the ocean's thermal structure indicates that, except in the high latitudes, only the upper mixed layer of the ocean is involved in greenhouse warming. The latest 3-D climate models support this. In fact, in the greenhouse warming scenario, the ocean becomes more statically stable and contains less coupling between the top and bottom, except for some regional features in the high latitudes.

Several sample computations with the 1-D model with different ocean depths are enclosed.

Next week I will be attending meetings in Washington, DC, including the White House Conference on Science and Economics Research Related to Global Change. I will bring along a floppy disk containing a 1-D model with interactive oceans, and, at your convenience, I could install the model on your computer.

Sincerely,



Warren M. Washington, Director
Climate & Global Dynamics Division

Telephone: (303) 497–1321
Fax: (303) 497–1137
E-Mail: warren washington@ncar.ucar.edu

Enclosures:

1. Figures 2.12 and 2.13
2. Documentation of the column radiation and cloud model
3. Reprint by Robert Dickinson on simple climate model

cc: D. Allan Bromley
Nancy Maynard
Daniel Albritton

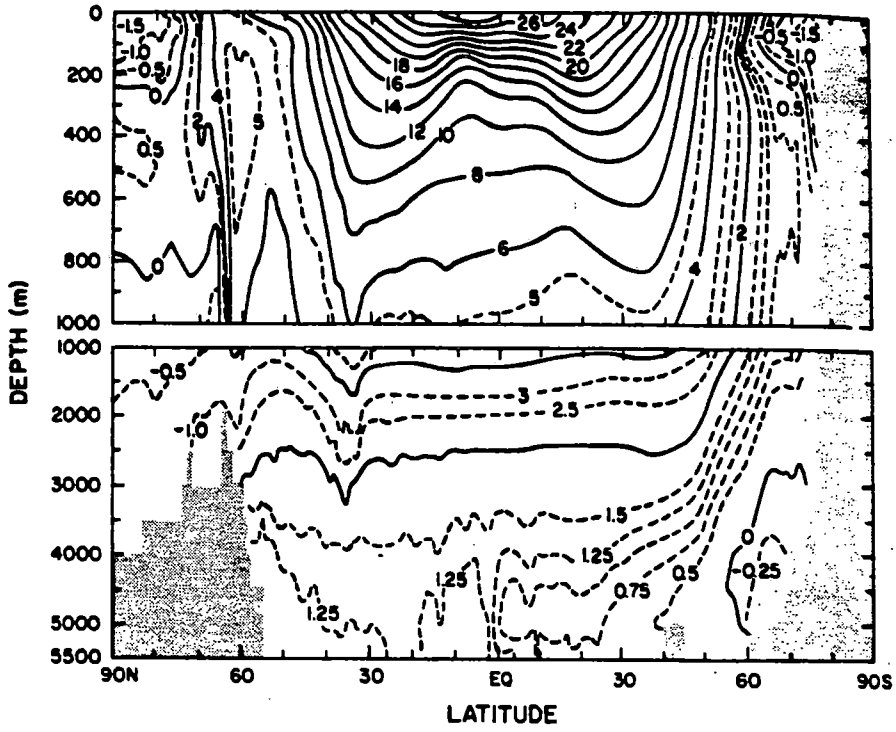


Fig. 2.12 Annually averaged ocean potential temperature (in °C) as a function of latitude and depth. [Redrawn from Levitus (1982).]

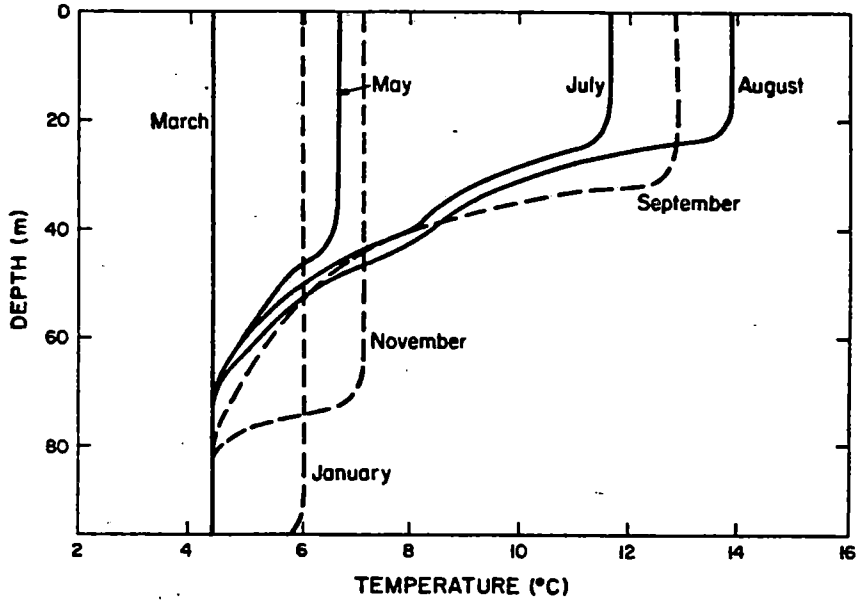


Fig. 2.13 Standard ocean temperature profiles in the Northern Hemisphere mid-latitudes in January, March, May, July, August, September, and November. [After Knauss (1978).]

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01. Memo	From D. Allan Bromley to John Sununu Re: IPCC Summary Report (2 pp.)	7/2/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: Global Warming 1990 (1 of 2) [3]

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(Document Follows)
By SP (NLGB) on 10/28/05

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FOIA/SYS Case #:	1998-0004-F[1]	**Appeal Case #:**	
Re-review Case #:	2005-0426-S	**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
AR Case #:		**MR Case #:**	
AR Disposition:		**MR Disposition:**	
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(b)(9) Release would disclose geological or geophysical information

THE WHITE HOUSE
WASHINGTON

July 2, 1990

Memo to: John Sununu
From: Allan Bromley
Re: IPCC Summary Report.

As you recall, Bob Watson and Ted Bernthal went to Geneva two weeks ago to work with Bert Bolin to draft an IPCC final summary report. Bolin had prepared a good draft and the assumption was, on our part, that the working group chairmen, each with a backup (Watson in our case) would work with Bolin to massage the draft and include suggestions such as those Dan Albritton had made.

In the event, Bolin lost control of the meeting and instead of finalizing a draft for presentation at the IPCC Plenary in early August, the entire

structure and content of the report were opened up without too much agreement or conclusion.

At the end of the meeting Balin was sent off to try again. I am enclosing herewith a copy of the second draft that we have just received from Balin. I have not yet read it but am told that the deadline for comments is COB today (Monday)

I feel certain that this can be stretched for a day or so.

I shall be happy to try to inject any comments you may have into the system — but realize that you have many other things on your mind.

Best Regards.

Allan

(Sent by FAX, July 2)

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Best Regards.

Allan

(Sent by Fax, July 2)

- Executive Summary to arrive today 7/2/90 - will send when available

United States Department of State

Bureau of Oceans and International Environmental and Scientific Affairs

Washington, D.C. 20520

RAPIDFAX TRANSMISSION Date 6/29/90

TO:

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___ CEA:Richard Schmalensee, tel 395-5036, fax 395-6947
_X_ CEQ:John Cohrssen, tel 395-5750, fax 395-3928
___ DOC:Alan Dunn, tel 377-0614, fax 377-8836
___ DOC/NWS:Martin Yerg, tel 427-7645, fax 587-4524
___ DOC/NOAA:William Sprig, tel 673-5360, fax 673-5355
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_X_ DOE:Richard Williamson, tel 586-5493, fax 586-3047
___ DOE:Ted Williams, tel 586-2061, fax 586-2062
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_X_ DOI:Indur Goklany, tel 208-4951, fax 208-4867
___ DOI:John Schefter, tel 648-6800, fax 648-5295
_X_ DOJ:Jonathan Wiener, tel 514-2744, fax 514-0557 for Dick Stewart
___ EPA:Jack Fitzgerald, tel 382-4034, fax 252-0780
___ EPA:Dennis Tirpak, tel 475-8825, fax 252-0780
_X_ EPA:Dick Morgenstern, tel 382-4034, fax 252-0780
___ EPA:Alan Hecht, tel 382-4870, fax 382-4470
___ EPA:Sandy Vogelgesang, tel 382-4870, fax 382-4470
___ EPA:Pat Koshel, tel 382-4880, fax 382-4470
___ HUD:Truman Goins, tel 755-7894, fax 755-0299
___ NSF:Eugene Bierly, tel 357-9874, fax 357-7745
___ NSF:Fred Bernthal, tel 357-9427, fax 357-9725
___ NASA:Bob Watson, tel 453-1681, fax 755-2552
___ NASA:John Theon, tel 453-1680, fax 755-2552
_X_ OMB:Norman Hartness, tel 395-6840, fax 395-6899
_X_ OSTP:Nancy Maynard, tel 456-6202, fax 395-3261
___ Treasury:Michael Springer, tel 343-0275, fax 786-8452
___ Treasury:Nelson Coar, tel 566-2487, fax 566-8066
___ Transportation:Courtney Tucker, tel 366-9524, fax 366-7483
_X_ USDA:Gary Evans, tel 447-5035, fax 755-7842
___ USDA:Norton Strommen, tel 447-9805, fax 472-5805
___ USIA:Wendy Beaver, tel 485-2757, fax 485-6520
___ USTR:Robert Reinstein, tel 395-5656, fax 395-3911
___ White House:Barry McBee, tel 456-2800, fax 456-2223
___ White House:Jeff Holmsted, tel 456-7803, fax 456-7929
___ White House:Andrew Card, tel 456-2533, fax 456-2397

FROM: OES/EGC Dan R.
OES/EGC: tel 647-4069, fax 647-5947

36 PAGES TO FOLLOW

COMMENTS

OVERVIEW AND CONCLUSIONS

Climate Change: a key Global Issue

The consideration of the Final Report by the World Commission on Environment and Development by the UN General Assembly in 1987 brought the issue of a possible future man-induced climate change to world attention and recognition. In 1988, following the decisions of the Tenth World Meteorological Congress, its Executive Council and the 14th session of the Governing Council of the United Nations Environment Programme (UNEP), the Executive Heads of the World Meteorological Organization and UNEP pursued the issue by inviting all nations of the UN to take part in a more elaborate study of a possible man-induced climate change. The first meeting on such a study was held in Geneva in November 1988, in which 30 countries participated. The Intergovernmental Panel on Climate Change (IPCC) thus formed, and open to all countries, agreed on the following tasks (see reference 1):

1. assessment of available scientific information on climate change;

2. assessment of environmental and socio-economic impacts of climate change;

3. formulation of response strategies.

The Panel set up Working Group I on Science, Working Group II on Impacts and Working Group III on Response Strategies to carry out the three tasks listed above.

At its second meeting held in Nairobi in June 1989, IPCC responded to the request by the UN General Assembly (see reference 2) to present its First Assessment Report in September 1990, to be available to the UN General Assembly later that year. The present report is an outcome of the deliberations by the Panel and its Working Groups. At its third session held in Washington D.C. in February 1990, IPCC responded to the request of the Noordwijk Ministerial Conference on Atmospheric Pollution and Climate Change to examine the feasibility of various options to stabilize and/or reduce emissions of carbon dioxide and other greenhouse gases. This work is now under way.

It should be emphasized that the issue of a possible man-induced climate change is very different from any other environmental issue that has emerged. It is a truly global problem, and will be a concern for all countries. Although the contributions to the emissions of greenhouse gases into the atmosphere are very different and will remain so in the future, all countries will be influenced in one way or another. Joint actions by all countries will be required in order to prevent or mitigate the consequences of climate change.

The IPCC's objective has been to provide the scientific and technical basis for action. It is clear that the present overview, supported by the extensive working group reports and their policymakers summaries, that some very specific general conclusions can already be drawn from this first phase of broad assessment of the issue, although many uncertainties remain. It should constitute a useful synthesis for our present knowledge that could serve as basis for negotiations about how to deal with the issue. It is, however, also obvious that we are facing a very difficult problem, and there will be no simple solutions.

The following overview of the IPCC Assessment presents a synthesis of the most important conclusions that have been reached by the Working Groups and are judged to be of particular importance for the political analyses and the negotiations that will begin after the fourth IPCC plenary meeting. To address more specific questions, in an analysis of this major environmental issue, reference is made to the Working Group reports.

The Scientific Issue

Increasing Greenhouse Gas Concentrations

It is first of all important to emphasize that although uncertainties exist with regard to the likelihood and the character of human-induced climate change, we do know some things with considerable certainty. Working Group I has structured its Policy-makers' Summary to distinguish clearly between:

- what we know with certainty
- what we calculate with confidence
- what is predicted by current models
- what our best judgement is on matters that are more uncertain

First it is stated that we are certain of the following:

- there is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be.

- emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These increases

warming of the Earth's surface.

The table below summarizes the present and pre-industrial abundances, current rates of change and present atmospheric lifetimes of greenhouse gases influenced by human activities. Carbon dioxide, methane, and nitrous oxide all have significant natural and human sources, while the chlorofluorocarbons are only produced industrially.

SUMMARY OF KEY GREENHOUSE GASES AFFECTED BY HUMAN ACTIVITIES

	Carbon Dioxide	Methane	CFC-11	CFC-12	Nitrous Oxide
Atmospheric concentration	ppmv	ppmv	pptv	pptv	ppbv
Pre-industrial (1750-1800)	280	0.8	0	0	288
Present day (1990)	353	1.72	280	484	310
Current rate of change per year	1.8 (0.5%)	0.015 (0.9%)	9.5 (4%)	17 (4%)	0.8 (0.25%)
Atmospheric lifetime (years)	50-200	10	65	130	150

ppmv = parts per million by volume; ppbv = parts per billion (thousand million) by volume;
pptv = parts per trillion (million million) by volume.

Since the industrial revolution the combustion of fossil fuels and deforestation have led to an increase of 26% in carbon dioxide concentration in the atmosphere. Methane concentrations have more than doubled because of rice production, cattle rearing, biomass burning, coal mining and ventilation of natural gas; also, fossil fuel combustion may have also contributed through chemical reactions in the atmosphere which reduce the rate of removal of methane. CFCs, which were not present in the atmosphere before their invention in the 1930s, are used as aerosol propellants, solvents, refrigerants and foam blowing agents. The total increase of all human-made greenhouse gas emissions is at present equivalent to an increase of carbon dioxide since pre-industrial times of about 50%.

The scenario assumes that, although oil and natural gas will play an important role as energy sources for several decades into next century, the major energy supply will be from coal, while renewable and nuclear energy sources are judged not to play a more important role globally until well into the 21st century. Account has been taken of the Montreal Protocol for reducing the emissions of the CFC-gases but not the possibility of phasing

55 increase of greenhouse concentrations will be
56 equivalent of a doubling of the carbon dioxide concentration by
about 2025 and quadrupling during the latter part of next century

although the scenario is most uncertain beyond the middle of next century. Emissions in 1985 and 2025 in the Business-as-Usual scenario are given in the table below.

	1985	2025
carbon dioxide (GtC)	5.9	11.5
methane (Tg)	541	761
nitrous oxide (Tg)	13	16
CFCs and HCFCs (Mt)	740	1900

It is interesting to note that national plans for the future (Reference Scenario; Working Group III) show a somewhat greater increase of carbon dioxide and methane emissions until 2025 than implied by the Business-as-Usual scenario.

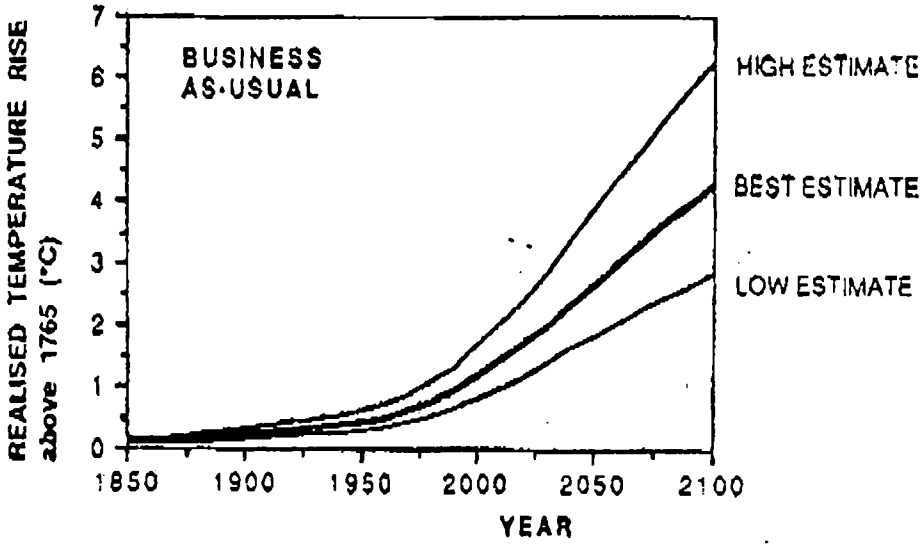
The anthropogenic fluxes of CO2 are much smaller (approx. 6Gt C/year) than the natural exchange fluxes (200Gt C/year) which occur between the atmosphere and the terrestrial biota and between the atmosphere and the oceans. Note that the figure should also include the emissions due to deforestation and changing land use. However, the anthropogenic fluxes have been large enough to modify significantly the natural balance during pre-industrial times as evidenced by the 25% increase of atmospheric carbon dioxide during the last 200 years.

Man-induced climate change

It is relatively easy to determine the direct effect of the increased radiative forcing due to increases in greenhouse gases. However, as climate begins to warm, various processes act to amplify (through positive feedbacks) or reduce (through negative feedbacks) the warming. The main feedbacks which have been identified are due to changes in atmospheric water vapour, clouds, sea-ice and the oceans.

The best tools we have which take the above feedbacks into account are mathematical models of the climate system which synthesise our knowledge of the physical and dynamical processes and allow for the complex interactions between the various components. However, in their current state of development, the descriptions of many of the processes involved are comparatively crude. Because of this, considerable uncertainty is attached to these predictions of climate change, which is reflected in the ranges of values given below. Based on current model results the rate of increase of temperature is estimated by WGI to be about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C this is greater than any changes seen over the past 10,000 years. This will result in a likely increase in global mean temperature

above pre-industrial) before the end of the next century with an uncertainty range of about 50%. The projected temperature rise out to the year 2100, with high, low and best-estimate climate responses, is shown in the diagram below. Because of other factors which influence climate, we would not expect the rise to be a steady one.



The temperature rise shown above is the realised temperature; due to the delaying effect of the oceans at any given time we would also be commited to a further temperature rise which would become apparent in decades to a century. Models predict that the realised temperature rise at any time is between 50 and 80% of the committed temperature rise.

It is finally important to recognize that a climate change that has occurred because increase concentrations of greenhouse gases in the atmosphere will disappear only slowly, even if all man-induced emissions would be stopped instaneously. This is due to the fact that the life-times in the atmosphere of the major greenhouse gases with which we are concerned, carbon dioxide, nitrous oxide and the CFC-gases about half a century to a few centuries. From a point of view, a climate change due to increasing amounts of greenhouse gases in the atmosphere is irreversible.

How much confidence do we have in our predictions?

There are many uncertainties in our predictions, particularly with regard to the timing magni tude and regional patterns of climate change. These uncertainties arise from our imperfect knowledge of:

- future rates of human-made emissions
- how these will change the atmospheric concentrations
- the response of climate to these changed concentrations

36 Finally, it is obvious that the extent to which climate will change depends on the rate at which greenhouse gases (and other

gases which affect their concentrations) are emitted. This in turn will be dependent on various complex economic and sociological factors.

Secondly, because we do not fully understand the sources and sinks of the greenhouse gases, there are uncertainties in our calculations of future concentrations arising from a given emissions scenario. Furthermore, because natural sources and sinks of greenhouse gases are sensitive to a change in climate, they may substantially modify future concentrations. It appears that, as climate warms, these feedbacks will lead to an overall increase, rather than decrease, in natural greenhouse gas abundances. For this reason, climate change is likely to be greater than the estimates we have given.

Thirdly, climate models are only as good as our understanding of the processes which they describe, and this is far from perfect. The ranges in the climate predictions given above reflect the uncertainties due to model imperfections; the largest of these is cloud feedback (those factors affecting the cloud amount and distribution and the interaction of clouds with solar and terrestrial radiation). Note a factor of two is larger than the total uncertainty range. Others arise from the transfer of energy between the atmosphere and ocean, the atmosphere and land surfaces, and between the upper and deep layers of the ocean. The treatment of sea-ice and convection in the models is also crude. Nevertheless we have substantial confidence that models can predict at least the broadscale feature of climate change, and we are confident that existing reliability of the predictions can be improved by further research.

Furthermore, we must recognise that our imperfect understanding of climate processes (and corresponding ability to model them) could make us vulnerable to surprises; just as the human-made ozone hole over Antarctica was entirely unpredicted. In particular, the ocean circulation, changes in which are thought to have led to periods of comparatively rapid climate change at the end of the last ice age, is not well observed, understood or modelled.

Testing Model Computations against Observations

It is of course essential to test model calculations against reality in order to validate the results.

We know from observations that the global mean temperature has increased between 0.3oC and 0.6oC, since the middle of last century and that most of this change has occurred primarily during two periods, i.e., the first four decades of this century and since 1975. Working Group I has carefully considered the criticism that local warming at observations sites within or in the vicinity of densely populated regions may explain some part of the observed change; such urban biasses have

55 ---- the record. ---- been removed
56 When trying to validate the model computations with the aid

of these observations a further complication arises in that the global mean temperature has not been increasing steadily; even a slight decline was observed in the Northern Hemisphere during the period 1949 -1975. Such irregular variations of the global mean temperature by several tenths of a degree are to be expected due to internal interactions (eg between ocean and atmosphere) in the climate system. These natural variations further obscure the warming trend that may result from increasing amounts of greenhouse gases in the atmosphere.

The size of the warming over the last century is broadly consistent with the predictions of climate models, but is also of the same magnitude as natural climate variability. If the sole cause of the observed warming were the human-made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability; alternatively this variability could have offset a still larger man-made greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more, during which time the commitment to future climate change would have grown considerably larger than it is today.

Regional Patterns of Climate Change

Knowledge of the global mean warming is of limited use in determining the impacts of climate change, for instance on agriculture. For this we need to know changes of temperature and precipitation regionally and seasonally. Models predict that regional climate changes will be different from the global mean. For example, temperature increases in Southern Europe and central Northen America are predicted to be higher than the global mean, accompanied on average by reduced summer precipitation and soil moisture. In general, confidence in regional estimate is low, especially for the changes in precipitation and soil moisture. Therefore we cannot yet give reliable regional predictions at the smaller scales demanded for impacts assessments.

A completely different, and potentially useful way of predicting patterns of future climate is to search for periods in the past when the global mean temperatures were similar to those we expect in future, and then use the past spatial patterns as analogues of those which will arise in the future. Paleo-climatological information can provide useful insights into climate processes, and can assist in the validation of climate models. In addition, paleo-analogue scenarios are useful for sensitivity studies to evaluate regional impacts of climate change.

Changes in the variability of weather and the frequency of extremes will generally have more impact than changes in the mean climate at a particular location. With the possible exception

an increase in mean temperature, episodes of high temperatures will most likely become more frequent in the future, and cold episodes less frequent.

Environmental Impact of Climate Change and Socio-Economic consequences

Impacts and Sensitivity

Because we are not yet able to foresee future likely changes of the regional distribution of climate with much accuracy we cannot predict more specifically the probable impacts of regional changes and are therefore limited to assessing them in rather general terms. Quantitative assessments of the socio-economic implications of a climate change for specific regions and countries are not either yet possible. We can, however, analyze the sensitivity of the environment to a given change of climate and much of what is brought out in the report of the Working Group II should be interpreted in that way.

Our ability to make more precise assessments of the impacts of global change will only come gradually during the 1990s, as regional predictions of climate change become more reliable.

The Working Group II Report concludes that:

The uncertainty of the regional predictions of climate change at present, limits our possibility to assess quantitatively the impacts of such a change. For the time being we rely on sensitivity analyses for the assessement of the likely impacts, which should, however, yield rather clear qualitative views about the vulnerability of nations to such changes. This uncertainty about the spatial characteristics of regional and local changes of climate must not overshadow the earlier conclusion that a significant change of the global mean temperature is associated with larger changes on the regional and local scale.

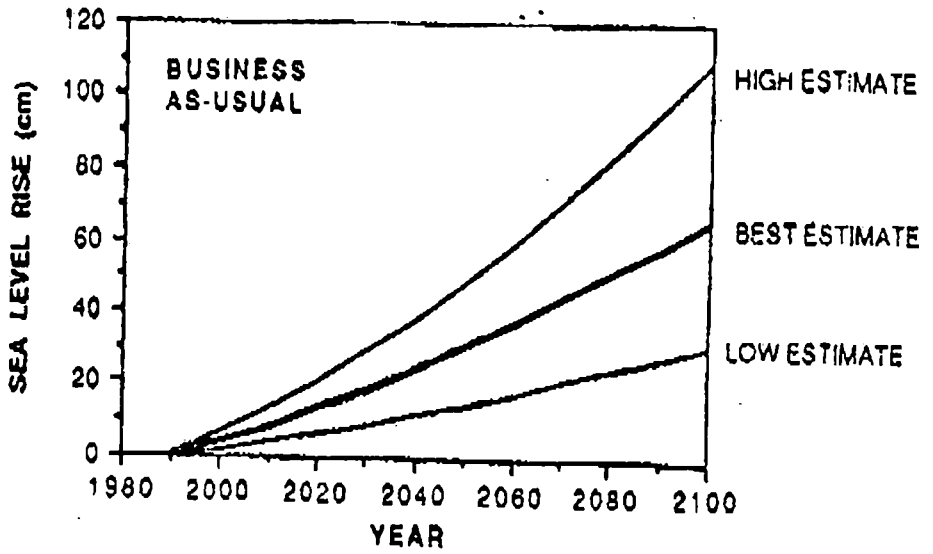
A climate change will bring with it both positive and negative impacts, although the negative ones will dominate (cf Working Group II). It is likely that, to a greater or lesser extent, all countries will be affected either directly or indirectly by climate change.

A rising sea level and its impacts

A warmer climate will induce a rise of the sea level, partly due to the expansion of sea water when being warmed. The response of the ice sheets over Greenland and particularly in the Antarctica is more uncertain, since both accumulation (due to change of snowfall) and melting is influenced by a change of climate. Working Group I concludes that:

55 under the IPCC Business-as-Usual emissions scenario, an average
56 rate of global mean sea level rise of about 6cm per decade over

under the IPCC Business-as-Usual emissions scenario, an average rate of global mean sea level rise of about 6cm per decade over the next century (with an uncertainty range of 3-10cm per decade is expected); this is three to six times faster than that seen over the last 100 years. The predicted rise is about 20cm in global mean sea level by 2030, and 65cm by the end of the next century, more detail is shown in the diagram below. There will be significant regional variations. Furthermore, even if greenhouse forcing stabilised, there would still be a commitment to a continuing sea level rise for many decades and even centuries, due to delays in climate, ocean and ice mass responses.



These values are less than those given in earlier assessments, particularly the upper bounds. The lower values do not give rise to an immediate concern except in the coastal areas of some countries with extensive coastlines of low-lying land and for some island states. The Working Group II recommends a more precise assessment of the risks to coastal areas and islands and to living resources caused by a 0.3-0.5 m rise of sea level which might be expected towards the latter part of next century, if no preventive measures were taken.

The slowly rising mean sea level is not an immediate threat. Increased damage will rather be experienced during storms, when short term variations of sea level induced by winds and by high waves would cause more destructive flooding. Delta regions of major rivers are obviously sensitive and often also heavily exploited for agricultural production.

The rise of sea level might threaten some low island and coastal zones by the middle of next century. A one meter rise, which is at the upper limit of what might occur in 100 years time, would impact 360,000 km of coastline (Working Group III), would render some island countries uninhabitable, displace tens of millions of people, seriously threaten low-lying urban areas flood productive land and coastal

The West Antarctic Ice Sheet is of special concern because a large part of it is grounded far below sea level. However, Working Group I concludes that "within the next century, it is not likely that there will be a major outflow of ice from the West Antarctica due directly to global warming".

Impacts on land, water and ecosystems

Turning next to the more difficult question of impacts of climate change on land, water and ecosystems, it is first important to recognize that a warmer climate is not necessarily harmful, if precipitation is adequate. The ecosystem composition might of course change, which in turn would imply the loss of plant species.

It is likely, however, that the distribution of precipitation would change and that soil moisture predominantly might decrease in continental regions. A change of the distribution of climatic zones would probably also occur and be associated with large regional local changes. Some ecosystems might well have difficulties to adjust in this process. Working Group II Policymakers' Report gives a more detailed analysis of the expected impacts in the case of the Business-as-Usual, Scenario A. Some key features of these impacts as described by Working Group II have been extracted for the present overview.

"Changes of climate would have an important effect on agriculture, including livestock. Studies have not yet conclusively determined whether on average, global agricultural potential would increase or decrease. Negative impacts could be felt at the regional elevel" and "there may be severe effects in some regions, particularly decline in production in regions of high present-day vulnerability, that are least able to adjust." These include Brazil, Peru, Sahel, S.E. Asia, Asian USSR and China. "Patterns of agricultural trade could be altered by decreased cereal production in some of the currently high-production areas." Although not analyzed more specifically, the supply of food would become more vulnerable to disturbances caused by changes of climate in a world with a rapidly growing population.

"The rotation period of forests is long and current forests will mature and decline in a climate, to which they are increasingly more poorly adapted. "Major forest-type zones and species ranges in the Northern Hemisphere could shift significantly as a result of climate change." "The most sensitive areas will be where species are close to their biological limits in terms of temperature and moisture", as "for example in semi-arid areas. Social stresses can be expected to increase and consequent damage to forest may occur. These increased and non sustainable uses will place more pressure on forest investments, forest conservation and sound forest management."

"Natural terrestrial ecosystems would be markedly influenced

because the rates of projected climatic change are likely to be faster than the ability of some species to respond. Flora and fauna would lag behind these climatic shifts and could find themselves in a different climatic regime. Major vegetation zones could face severe disturbances and disruptions, influencing plant and associated animal populations". "Species could disappear and lead to substantial reduction in biological diversity". "The socio-economic consequences of these impacts will be significant, especially for those regions of the globe where societies and related economies are dependent on natural terrestrial ecosystems for their welfare. Changes in the availability of food, fuel, medicine, construction materials and income are possible as these ecosystems are changed. Important fibre products could also be affected in some regions."

Enhanced carbon dioxide concentratios in the atmosphere would increase the water-use efficiency in the process of photosynthesis which might enhance growth for certain plants in some regions of the globe, which might be beneficial in agriculture and forestry as well as for natural ecosystems. "Consequences of CO_2 enrichments and climate change could be modified by other environmental factors, both natural and man-induced (e.g. by air pollution)."

"Relatively small climate changes can cause large water resource problems. In many areas, especially in arid and semi-arid regions and those humid areas where demand or pollution has led to water scarcity." While "many areas will have increased precipitation, soil moisture will decrease in other areas, particularly in those that are "already in marginal situations such as the Sahelian zone in Africa." Increased drought risk represents potentially the most serious impact of climate change on agriculture. "Future design in water resources engineering will need to take possible impacts into account when considering structures with life span to the end of the next century", but necessary analyses are uncertain at present because of the lack of adequate regional predictions.

"Global warming can be expected to affect the availability of water and biomass, both major energy sources in many developing countries. These effects are likely to differ between and within regions with some areas losing and others gaining water and biomass. Such changes in areas which lose water may jeopardise energy supply and materials for human habitation and energy."

It is obviously difficult to judge how serious a climatic change might be to an individual nation, or to humankind as a whole, on the basis of the still largely qualitative findings as given in the Working Group II report.

Means to integrate more quantitatively the implications of these many possible impacts, both positive and negative, are needed. The impacts as briefly described call for careful

consideration of the consequences of climate change in the developments of plans for resource use and management.

Impacts on People

Direct impacts of climate change on people are modest. A warmer climate may imply, however, that previously hot places become even hotter. Even though this may cause problems for elderly and sensitive people, it usually cannot be considered as a serious problem.

Changing climate could, on the other hand, affect human settlement and change the geographical distribution of deceases in the world and stimulate a spread of epidemic diseases. The IPCC recognizes the views as expressed by Working Goup II, that

"The most vulnerable human settlements are those especially exposed to natural hazards, e.g. coastal or river flooding, severe drought, landslides, severe wind storms and tropical cyclones. Most vulnerable populations are in developing countries, in the lower income groups, residents of coastal lowlands and islands in semi-arid and in grasslands."

"Changes in precipitation and temperature could radically alter the patterns of vector-borne and viral diseases by shifting them to higher latitudes and thereby putting large populations at risk." This could initiate migrations of people in turn leading to disruptions of settlement pattern and social instability in some areas."

Reducing emissions of greenhouse gases -- the scope of the problem

Emission Scenarios

As pointed out above, man's emissions of greenhouse gases have enhanced their concentration in the atmosphere so that their present integrated effect is equivalent to a concentration of carbon dioxide in the atmosphere of about 150% of the pre-industrial concentration. Half of this increase has occurred in less than 25 years. The analysis of different scenarios of the future increase of greenhoude gasses in the atmosphere show that the equivalent carbon dioxide concentration in the atmosphere probably measures to limit future emissions were taken. Before considering what measures to limit future emissions might be justified, it is important to recognize the very major efforts that are required in order to slow down or to halt climate change.

The Scope of the Problem

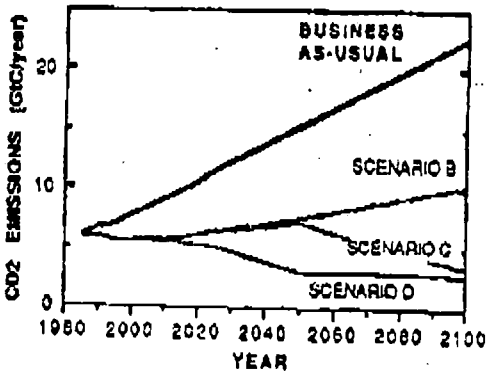
It is important to clarify first the relative importance of the different greenhouse gases in bringing about a climate change. We need to understand the difficulties that will be encountered in efforts to reduce their emissions and thereby to slow down their rates of increase or ultimately to stabilize

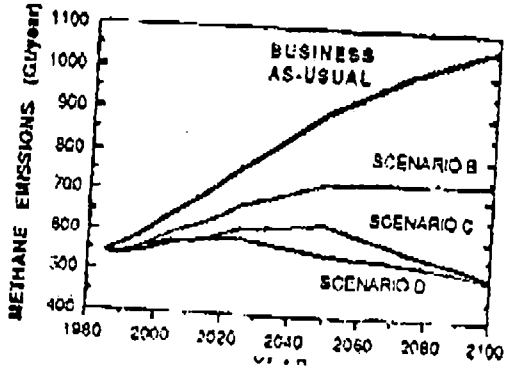
their atmospheric concentrations.
Working Group I and III have presented relative contributions to the additional forcing (heating) of the atmosphere during the period 1765 - 1990, the last decade and their predicted contributions for the period 2000 - 2025 under the Business-as-Usual, (in percent);

	1765-1990	1980-90	BaU 2000-25
Carbon dioxide	61	55	63
Methane	23	15	17
CFC	12	24	7
HCFCs	0	0	8
Nitrous Oxide	4	6	5

(Ozone may be an important contributor, but its effects are difficult to quantify and have not been included above)

The recent (1980 - 1990) reduction in the proportion of forcing change due to carbon dioxide is primarily due to the very rapid increase in the role of the CFC-gases as forcing agents. Because of the Montreal agreement on limiting the use of CFC-gase, the relative contribution of carbon dioxide as a heating agent will increase throughout the 21st century according to the Business-as-Usual scenario. Working Group III has developed three other scenarios, all having the same assumptions about population growth as the Business-as-Usual (Scenario A). The man-made emissions of carbon dioxide and methane from all four WGIII scenarios are shown in the diagrams below.

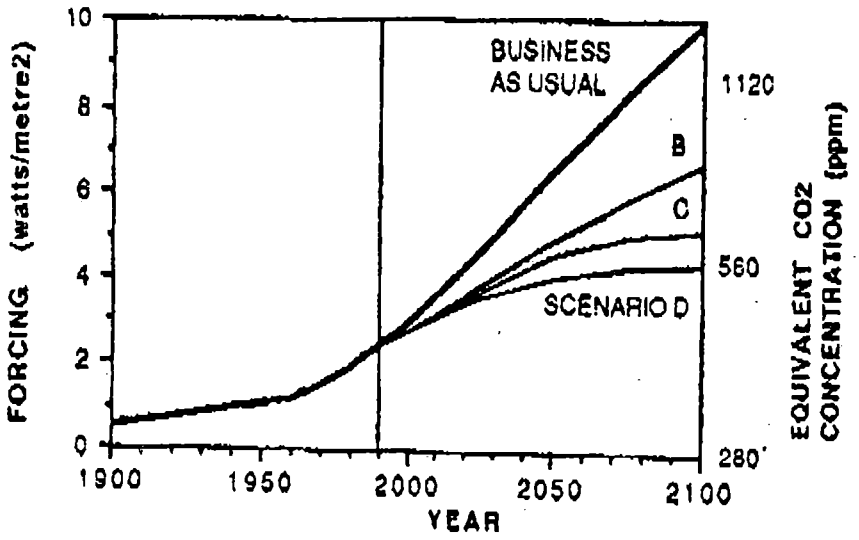




Scenario B, Low Emission, assumes the energy supply mix of fossil fuels shifts towards natural gas, large efficiency increases are achieved, deforestation is reversed and the Montreal Protocol on CFCs is fully implemented. This results in a doubling of equivalent carbon dioxide by about 2040.

Scenario C, Control Policies, assumes a shift towards renewable energies and nuclear energy takes place in the latter part of the next century, CFC-gases are phased out and agricultural emissions (methane and dinitrogen oxide) are limited; an equivalent doubling of carbon dioxide will occur in about 2050. It should be recalled that there is a 50% uncertainty range around each one of the curves shown in the figure.

Scenario D, Accelerated Policies; assumes a rapid shift to renewable energies and nuclear energy takes place early in the next century in the cases of Scenarios B, C and D will be between 70% and 50% of the stringent emission controls in industrial countries and moderate growth of emissions in developing countries. This scenario stabilises equivalent dioxide concentrations at about twice pre-industrial levels towards the end of the next century.



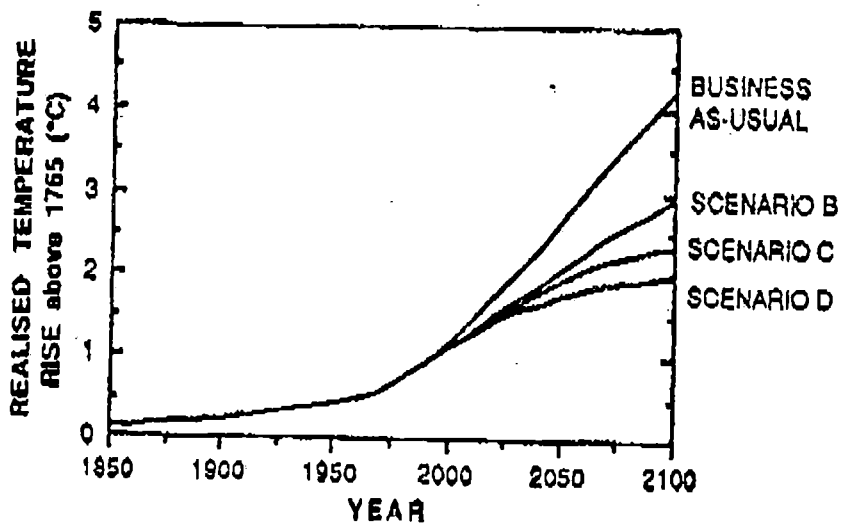
Contribution by Sector

"For the later analysis of possible measures to be implemented it is of interest also to give the relative contributions to the enhanced radiative forcing during the decade of the 1980s and the projected distribution for the period 2000 - 2025 by sector. The still relatively large contribution from CFC-gases is due to the assumption made that these will largely be replaced by HCF and HCFC-gases" The numbers given in the text should be presented in a table and the

55 ... from the different greenhouse gases as presently
56 also included can be deleted, since they have been given earlier in the report.

Climate change when emissions are controlled

Under the other Working Group III emission scenarios which assume progressively increasing levels of controls, rates of increase in global mean temperature are predicted to be about 0.2oC per decade (Scenario B), just above 0.1oC per decade (Scenario C and about 0.1oC per decade (Scenario D). Further details are shown in the diagram below.



Sea level rise by the end of the next century will be between 50% and 70% of the Business-as-Usual scenario.

Reducing emissions of greenhouse gases

To limit future climate change we need to examine the effectiveness of reductions in the emissions of each of the greenhouse gases. Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes in emissions. Continued emissions of these gases at present rates would commit us to increased concentrations for centuries ahead. The longer emissions continue to increase at present day rates, the greater reductions would have to be for concentrations to stabilise at a given level (see diagram below). The long-lived gases would require immediate reductions in emissions from human activities by more than 60% in order to stabilise their concentrations at today's levels; methane would require a 15-20% reduction.

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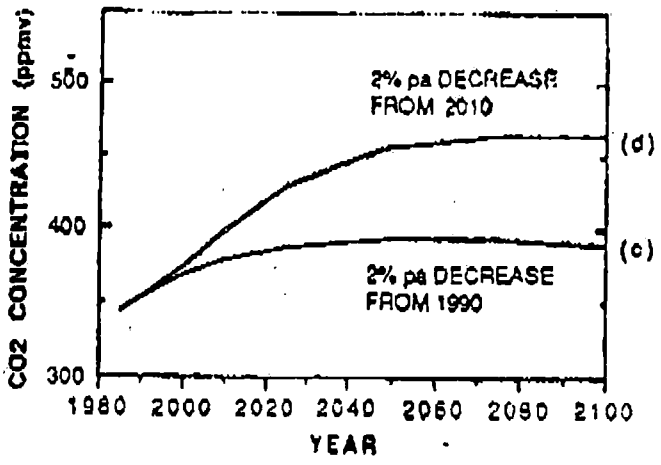

(c) emissions reduced by 2% pa from 1990
(d) emissions reduced by 2% pa from 1990 to 2010, Then reduced by 2% pa

There are other technical criteria which may help policymakers to decide, in the event of emissions reduction being deemed necessary, which gases should be considered. Does the gas contribute in a major way to current, and future, climate forcing? Does it have a long lifetime, so earlier reductions in emissions would be more effective than those made later? And are its sources and sinks well enough known to decide which could be controlled in practice? The table below illustrates these factors.

GAS	MAJOR CONTRIBUTOR?	LONG LIFETIME?	SOURCES KNOWN?
Carbon dioxide	yes	yes	yes
Methane	yes	no	semi-quantitatively
Nitrous oxide	not at present	yes	qualitatively
CFCs	yes	yes	yes
HCFCs, etc	not at present	mainly no	yes
Ozone	possibly	no	qualitatively

Chlorofluorocarbons

The Working Group I assessment clearly show that the CFC-gases are much more effective per kilogramme emitted in heating the atmosphere than any of the other greenhouse gases in today's atmosphere.

A reduction of the use of CFC-gases would be a cost-effective measure to contribute to the slowing down of global warming.

The role of the CGCs is expected to decrease because of the Montreal Protocol. It should be noted, however, that the CFCs will probably be partially replaced by HCFCs and HFCs which are weaker greenhouse gases because their atmospheric lifetimes are shorter than those of the CFCs. Still, because of the difficulties being encountered when attempting to prevent a further build up atmospheric greenhouse gases, serious consideration should be given to other replacements to the CFC-gases than HFCs and HCFCs as is now being proposed.

Methane, nitrous oxide and ozone

Reductions of the emissions of methane and particularly nitrous oxide are difficult to achieve, since they are primarily due to wide spread activities in society related to agriculture, forestry and waste management. Because the quantitative importance of each of these sources is not well known at present the effectiveness of different control strategies is hard to evaluate. We are less able to specify the sources of nitrous oxide; thus, strategies to reduce their emissions are even more difficult to develop. Tropospheric ozone is predicted to increase due to enhanced emissions of carbon monoxide, hydrocarbons and nitrogen oxides released mainly by transport and industry.

Carbon dioxide

It is clear from the analysis above that the major and increasing source of greenhouse emissions is due to the emission of carbon dioxide from fossil fuel combustion and deforestation. Carbon dioxide emissions are due to fossil fuel burning, at present 5.5 - 6.0 billion tons of carbon per year (GtC pa), and a net decrease of the terrestrial biosphere due to deforestation and changing land use of 0.6 -2.5 GtC pa in 1980 (at present probably somewhat larger). The total emissions are thus at present at least 6.5 - 8.5 GtC pa. The world population is about 5.2 billion and the emission per capita thus about 1.1 tons of carbon due to fossil fuel emissions and 0.35 billion tons due to deforestation and changing land use.

The emissions due to fossil fuel burning are, however, very unevenly distributed between regions of the world as shown in the following table:

Year: 1985	Carbon emissions billion tons of carbon per year	Carbon emissions tons of carbon per capita and year	Carbon emissions tons of carbon per GNP
Global Totals	5.15	1.06	
North America	1.34	5.08	
Western Europe	0.85	2.14	
OECD Pacific	0.31	2.14	
Centr. Planned Europe	1.33	3.19	
Africa	0.17	0.29	
Centr. Planned Asia	0.54	0.47	
Latin America	0.22	0.55	
Western Asia	0.13	1.20	
South and East Asia	0.27	0.19	

It is difficult to deduce accurate values for the carbon dioxide emissions due to deforestation and changing land use. It seems clear, however, from the reports by Working Groups II and III that the net emission of carbon dioxide from the tropics due to deforestation amounted to about 1.7 GtC pa (range 0.6-2.5) in 1980. The average emissions per capita in the tropical countries is about 1 ton of carbon per year while some with more intense exploitation of their forests account for a per capita emission that approaches that of industrial countries due to fossil fuel emissions.

"One the basis of the various emission scenarios and assuming that the global population is about 8 million in 2030, we compute the per capita emissions at that time to be (revised numbers from Jenkins) and that at due to deforestation and changing land use about 0.35 tons of carbon per year. If now, on the basis of the various emissions scenarios, we project the per capita emissions to the year 2070, assuming that the global population is 10 billion at that time, we arrive at the figures in the following table for the per capita emissions.

Scenario	CO2 (tC/capita)	Methane (t/capita)
Business-as-Usual	1.8	0.1
Scenario B	0.8	0.07
Scenario C	0.5	0.06
Scenario D	0.3	0.05

Noting that, only under scenario D is the carbon dioxide concentration stabilised, and then at a level 50% above pre-industrial, it is clear that achieving the figures in this table that achieving stabilisation of atmospheric carbon dioxide concentrations would require very major efforts by the global society. Even to reduce the rate of change of climate as in scenarios B and C would clearly be very difficult.

It is important in this context also to compare the possible importance of reducing the rate of deforestation and expanding reforestation. We note first that, at present, the total emissions of carbon dioxide due to man's use of the terrestrial ecosystems are about 25% of the total man-induced emissions of carbon dioxide into the atmosphere. A major decrease of the rate of deforestation would contribute significantly to slowing down the rate of carbon dioxide increase in the atmosphere, but not stop it.

It has been proposed that a major programme for reforestation should be initiated. The Noordwijk Ministerial Declaration in November 1989 requested the IPCC to explore the effects of an annual reforestation of 12 million hectares. Working Group I has calculated roughly the transfer of carbon from the atmosphere into the terrestrial biosphere that thereby would be achieved. If such a policy would be maintained for a period of 40 years an area as large as about 50% of the total area of the United States would have been reforested. By 2030, i.e. 40 years from now, about 25 billion tons of carbon would have been sequestered into the terrestrial biosphere, possibly somewhat more if also the soil carbon would increase. After 100 years the accumulated uptake might be 50-70 billion tons of carbon. This is 5-10% of the emissions of carbon dioxide into the atmosphere that is expected during these periods of time due to fossil fuel burning according to the Busines-as-Usual and the Reference Scenario. The practical difficulties of implementing such a policy have not been analysed by Working Group III.

A reduction of the rate of increase of carbon dioxide in the atmosphere by 10-15% could be achieved if the present rate of deforestation would be reduced to about half of the present rate. In tropical countries this would also contribute to maintaining biological diversity. A major program of reforestation as considered by the Noordwijk Ministerial Conference in November 1989 would play some role in slowing down the rate of increase of carbon dioxide in the atmosphere, but would at most reduce it by 5-10%, if fossil fuel use would continue to increase in accordance with the scenario Business-as-Usual (Scenario A).

Future Programme of the Working Groups

a. Science and Impacts

Because of the pace with which scientific research is advancing, it is vital that IPCC is provided with timely updates to its reports, so that policymakers are provided with the best foundation for their

deliberations. Whereas complete new assessments will probably not be required until about 1995, revisions in areas of major progress and greatest uncertainty should be made by about 1992. In addition, the capability should be provided to respond to ad hoc scientific questions which may arise from negotiations toward a climate convention.

Close liaison should be maintained with elements of WCP to ensure that latest scientific results contribute to the assessment process, and that the scientific programmes are structured to maximise their relevance to IPCC.

b. Response Stategies

(para from WG3)

Narrowing the Uncertainties

To improve our predictive capability, Working Groups I and II point out the need:

* to understand better the various climate related processes, particularly those associated with clouds, oceans and the carbon cycle;

* to improve systematic observation of climate variables on a global basis, and further investigate changes which took place in the past;

* to develop improved model of the Earth's climate system;

* to increase support for national and international activities especially in developing countries,

* to facilitate international exchange of climate data;

* to understand better the impacts of climate change on natural terrestrial and marine ecosystems, agriculture and forestry, water resources and human settlements and health;

In addition to the increased support for national activities, the required programme of research will need unprecedented international cooperation with the WCRP of WMO and ICSU and IGBP of ICSU playing vital roles. The IPCC points out that there is no need to establish new international mechanisms, but rather urges all countries to contribute to these programmes through their national efforts, and to increase financial support and assistance in kind to these programmes, and to the climate related components of WMO, UNEP, UNESCO and its IOC and FAO.

RESPONSE STRATEGIES

The scientific assessment of a possible man-induced climate change, the environmental and socio-economic consequences of such a change, and the difficulties we encounter in attempting to slow down or halt it calls for the development of strategies on a long term basis. The great diversity in the situation of different countries and their responsibilities for combatting climate change will have to be taken into account in such development. It is clear that this is not going to be a simple undertaking.

With time, we will learn more from further research and monitoring activities, and from experience with implementing limitation/adaptation measures. To take maximum advantage of such growing knowledge and experience, a flexible and progressive approach to addressing climate change is required.

Working Group III has addressed the issue of formulating response strategies. The following subsections are extracts of the main findings of the policymakers summary of that Working Group.

MAIN FINDINGS

The following findings have been identified as a basis for action now and in the future:

1) Climate change is a global issue; effective responses would require a global effort which may have a considerable impact on humankind and individual societies.

2) Industrialized countries and developing countries have a common responsibility in dealing with problems arising from climate change.

3) Industrialized countries should take the lead and have specific responsibilities on two levels:

   a) Major part of emissions affecting the atmosphere at present originates in industrialized countries where the scope for change is greatest. Industrialized countries should adopt domestic measures to limit climate change by adapting their own economies in line with future agreements to limit emissions;

   b) To co-operate with developing countries in international action without standing in the way of the latter's development by contributing additional financial resources, by appropriate transfer of technology, by engaging in close co-operation concerning scientific observation, by analysis and research, and finally by means of technical co-operation geared to forestalling and managing environmental problems.

4) Emissions from developing countries are growing and may

need to grow in order to meet their development requirements and thus, over time, are likely to represent an increasingly significant percentage of global emissions. Developing countries should, within the limits feasible, take measures to suitably adapt their economies.

5) Sustainable development requires the proper concern for environmental protection, as the necessary basis for continuing economic growth. Continuing economic development will increasingly have to take into account the issue of climate change. It is imperative that the right balance between economic and environmental objectives be struck.

6) Limitation and adaptation strategies must be considered as an integrated package and should complement each other to minimize net costs. Strategies that limit greenhouse gases emissions also make it easier to adapt to climate change.

7) The potentially serious consequences of climate change on the global environment give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of significant uncertainties.

8) A well-informed population is essential to promote awareness of the issues and provide guidance on positive practices. The social, economic and cultural diversity of nations will require tailored approaches.

Because large, projected increase in world population will be a major factor in causing the projected increase in global greenhouse gases, it is essential that global climate change strategies include strategies and measures to deal with the rate of growth of the world population.

Working Group III has also identified measures at the national, regional and international levels as applicable which, while helping to address the issue of climate change, can yield other benefits in the shorter term.

LIMITATION OF NET EMISSIONS FROM THE ENERGY SECTOR

The energy sector plays a vitally important role in economic well-being and development for all nations. At the same time, because energy production and use accounts for about one half of the radiative forcing from human activities, energy policies need to ensure that continued economic growth occurs in a manner that, globally, conserves the environment for future generations.

However, there is no single, quick-fix technological option for limiting greenhouse gas emissions from energy sources. A comprehensive strategy is necessary which deals with improving efficiency on both the demand and supply sides as a priority and emphsizes technological research, development, and deployment.

Achieving even a 20% reduction in CO_2 from current emission levels would require major changes in global energy markets, plans, and infrastructure, with intervention by governments. Maintaining this emission reduction goal would require continued

technological improvements, structural changes in the global economy, and changes in the proportion of carbon-based fuels utilized over the whole of the next century.

In the energy category, Working Group III especially noted that:

--Improved energy efficiency reduces emissions of carbon dioxide, the most significant greenhouse gas, while improving overall economic performance and reducing other pollutant emissions and increasing energy security;

--Use of cleaner energy sources and technologies reduces carbon dioxide emissions, while reducing other pollutant emissions that give rise to acid rain and other damaging effects.

Working Group III recognizes the particular difficulties which will be faced by countries, particularly developing countries, whose economy is heavily dependent on production and/or export of fossil fuels, as a consequence of actions taken by other countries to limit or reduce energy related greenhouse gas emissions. These difficulties should be taken into account when elaborating international strategies.

Various potential options have been identified for reducing greenhouse gas emissions from energy systems. The most relevant categories of options appear to be:

- efficiency improvements and conservation in energy supply, conversion, and end use;
- fuel substitution by energy sources which have lower or no greenhouse gas emissions;
- reduction of greenhouse gas emissions by removal, recirculation or fixation;
- management and behavioral changes (e.g. increased work in homes through information technology) and structural changes (e.g. modal shift in transport).

The potential for energy efficiency savings in a number of these options ranges from 15 to as much as 60% (see the Policymakers Summary of Working Group III).

The feasibility of a particular option depends on more than its technical potential alone. Important additional factors are its economic potential (economic efficiency and cost effectiveness) and its market potential (the likelihood of consumer acceptance, reflecting attitudes to risk and non-monetary costs).

The challenge to policy makers is to enhance the continual diffusion of technological options into the market place, to encourage behavioral and operational changes, and to address the broader issues outside the energy sector in order to capture more of the potential that exists.

LIMITATIONS OF NET EMISSIONS FROM THE AGRICULTURAL AND FORESTRY ACTIVITIES

Agriculture, forestry and other human activities are also responsible for substantial quantities of greenhouse gas emissions.

About 9 percent of anthropogenic greenhouse gas emissions can be attributed to the agricultural sector. Limitation of emissions from this sector presents a challenge because the processes by which greenhouse gases, in particular methane and nitrous oxide, are released in agricultural activities are not well understood. In addition, response options in the agricultural sector must be designed to ensure maintenance of food supply.

In the short term, reductions can be achieved through improved livestock waste management, altered use and formulation of fertilizers, and other changes to agricultural land use, without affecting food security.

Forestry practices and other human activities associated with land use, such as biomass burning and landfills, account for about 18 percent of anthropogenic greenhouse gas emissions. The forest crisis is rooted in the agricultural sector and in the human need for employment and income. Deforestation will be stopped only when the natural forest is economically more valuable for the people who live in and around the forests than alternative uses for the same land. Useful steps might include:

--Improved forest management and, where feasible, expansion of forest areas as possible reservoirs of carbon.

--Possible key elements of a world forest conservation protocol could be identified in the context of a climate convention process, that also addresses energy supply and use and practical means of implementing it.

--Use of forest products and wood could be strengthened and improved through measures such as substituting a portion of fossil energy sources by wood or other sustainable managed biomass;partial replacement of high energy input materials by wood; further recycling of forest products; and, improved efficiency of use of fuel wood.

LIMITATION BY PHASING OUT CFC'S UNDER THE MONTREAL PROTOCOL

CFCs represent a very important source of greenhouse gas emissions and account for about 25% of the total contributions to the enhanced radiative forcing for the period of the 1980s. Phasing out of CFCs under the Montreal Protocol would remove some of the most powerful and long-lived greenhouse gases, while also protecting the stratospheric ozone layer.

But the review of the Montreal Protocol <u>[now underway, may</u>

[illegible] as appropriate after London] should take into
account the global warming potential of proposed CFC

substitutes. For a given emission rate, HCFCs and HFCs are less effective greenhouse gases than the CFCs because of their shorter lifetimes. The growth rates assumed in the IPCC scenarios will result in the atmospheric concentrations of HFCs and HCFCs becoming comparable to the CFCs during the next several decades assuming that the CFCs had continued to be used at current rates.

MEASURES FOR ADAPTING TO GLOBAL CLIMATE CHANGE

In addition to the limitation options discussed above, Working Group III reviewed measures for adapting to potential climate change with respect to coastal zones and resource use management. These include:

--Developing emergency and disaster preparedness policies and programs.

--Assessing areas at risk from sea-level rise and developing comprehensive management plans to reduce future vulnerability of populations and coastal developments and ecosystems as part of coastal zone management plans.

--Improving the efficiency of natural resource use, research on control measures for desertification and enhancing adaptability of crops to saline regimes.

A programme could begin now to enable developing countries to implement coastal zone management plans by the year 2000. The programme would provide for training of country experts, data collection and technical assistance and co-operation.

IMPLEMENTATION MEASURES

Working Group III also considered several priority areas which must be addressed in order to adequately implement limitation or adaptation responses. These "implementation mechanisms" represent the primary vehicles through which national, regional and international responses to climate can be effected.

Public Information and Education

A well informed global population is essential for addressing and coping with an issue as complex as climate change. Because climate change would affect, either directly or indirectly, almost every sector of society, broad global understanding of the issue will facilitate the adoption and implementation of such response options as deemed necessary and appropriate. The dissemination of information also represents a powerful economic instrument for ensuring that markets accurately take into account potential consequences and/or opportunities of climate change.

Technology Development and Transfer:

development and transfer of technologies is vital to any effort to address global climate change. The development of new technologies may provide the means by which societies can

meet their energy, food, and other needs in the face of changes in global climate, while at the same time minimizing emissions of greenhouse gases.

Technological development, including improvement and reassessment of existing technologies, is needed to limit or reduce anthropogenic greenhouse gas emissions; absorb such gases by protecting and increasing sinks; adapt human activities and resource use and management to the impacts of climate change; and detect, monitor and predict climate change and its impacts.

There is a need for the rapid transfer of technology to the developing countries on a preferential basis, of technologies for addressing climate change. Developing countries are of the view that transfer of technologies on a non-commercial basis is necessary and that specific bilateral and multilateral agreements should be established to promote this. Some other countries where technologies are not owned by the government believe that transfer of technologies would be a function of commercial negotiations. The issue of intellectual property rights also presents a case where international opinion is mixed.

Economic Mechanisms

It is important that any potential measures to limit or adapt to global climate change be as economically efficient and cost-effective as possible, while taking into account important social implications.

In general, environmental objectives can be achieved either through regulations requiring the use of a specific technology or attainment of specified goals, or through economic instruments such as emissions fees, subsidies, sanctions, tradeable permits, or a comprehensive system that might address all greenhouse gas sources and sinks. Market based economic instruments encourage limitations in emissions by those who can achieve them at least cost. Careful and substantive analysis of the implications of such instruments is needed.

Economic instruments, through their encouragement of flexible selection of abatement measures, frequently offer the possibility of achieving environmental improvements at lower cost than regulatory mechanisms. Unlike many regulations, they tend to encourage innovation and the development of improved technologies and practices for reducing emissions. Economic mechanisms also have the potential to provide the signals necessary for more environmentally sensitive operation of markets. It is unlikely, however, that economic instruments will be applicable to all circumstances.

Financial Mechanisms

Industrialised and developing countries consider it important that assurances of financial mechanisms are needed for undertaking adequate measures to limit and/or adapt to climate change.

58 Financial resources channelled to developing countries would

be most effective if focused on those activities which contribute both to limiting greenhouse gas emissions and promoting economic development. Areas for cooperation and assistance could include:

- Efficient use of energy resources and the increased use of fossil fuels with lower greenhouse gas emission rate or non-fossil sources;

- Rational forest management practices and agricultural techniques which reduce greenhouse gas emissions;

- Facilitating technology transfer and technology development;

- Measures which enhance the capacity of developing countries to develop programs to address climate change, including research and development activities and public awareness and education;

- Participation by developing countries in international fora on global climate change, such as the IPCC.

Legal Measures

The measures noted above would require a high degree of international cooperation, with due respect for national sovereignty of states. To assist in that process, international negotiation on a framework convention on climate change should start as quickly as possible after the completion of the IPCC First assessment Report. This, together with any additional protocol(s) that might be agreed upon, would provide a firm basis for effective cooperation to act on greenhouse gas emissions and to adapt to any adverse effects of climate change.

The framework convention should, at a minimum, contain general principles and obligations. It should be framed in such a way as to gain the adherence of the largest possible number and most suitably balanced range of countries while permitting timely action to be taken.

Working Group III compiled a list of possible elements for a framework convention. The inclusion of any particular element in this list does not imply consensus with respect to that element, or the agreement of any particular government to include negotiating such a convention; these include:

- o the political imperative of striking the correct balances (a) between the arguments for a far-reaching, action-oriented convention and the need for urgent adoption of a convention so as to begin tackling the problem of climate change; and (b) among the risks of inaction, the costs of action and current levels of scientific uncertainty;

- o the extent to which specific obligations, particularly on the control of emissions of greenhouse gases, should

be included in the convention itself, possibly as annexes, or be the subject of a separate protocol(s);

- o the timing of negotiation of protocol(s) in relation to the negotiations on the convention;

- o the introduction as appropriate of sound scientific bases for establishing emission targets (such as total emission levels, per capita emissions, emissions per GNP, emissions per energy use, climatic conditions, past performance, geographic characteristics, fossil fuel resource base, carbon intensity per unit of energy, energy intensity per GNP, socio-economic costs and benefits or other equitable considerations);

- o the extent to which specific goals with respect to global levels of emissions or atmospheric concentrations of greenhouse gases should be addressed;

- o whether obligations should be equitably differentiated according to countries' respective responsibilities for causing and combatting climate change and their level of development;

- o the need for additional resources for developing countries and the manner in which this should be addressed, particularly in terms of the nature, size and conditions of the funding, even if detailed arrangements form the subject of a separate protocol;

- o the basis on which the promotion of the development and transfer of technology and provision of technical assistance and co-operation to developing countries should take place, taking into account considerations such as terms of transfer (preferential or non-preferential, commercial or non-commercial), assured access, intellectual property rights, the environmental soundness of such technology, and the financial implications;

- o the nature of any new institutions to be created by the convention (such as a Conference of the Parties, an Executive Organ, as well as other bodies), together with their functions, composition and decision-making powers, e.g., whether or not they should exercise supervision and control over the obligations undertaken;

- o the criteria, timing, legal form and incidence of any obligations to control the net emissions of greenhouse gases.

Strategies for the future

The major dilemmas

The conclusions of Working Group I show clearly that the scientific community essentially agrees about the climate changes that could occur if the present build-up of greenhouse gas emissions continues or even accelerates into the next century as projected by both the Scenario A (Business-as-Usual) and the Reference Scenario. Working Group II envisages potentially far-reaching environmental consequences of such changes. This threat to the global environment and its implications for countries and the peoples of the world must be weighed against the costs and other socio-economic implications for limiting, and/or adapting to, any adverse effects of climate change. It is, therefore, essential to address a few fundamental questions in this context.

The developed countries have emitted most of the greenhouse gases into the atmosphere that now cause us concern. The developing countries are rapidly increasing their emissions in striving for improving their living standards, particularly by increasing their use of fossil fuels as the prime source of energy. Cheap energy has in the past contributed substantially to the rapid increase of the standards of living in industrialized countries. They possess the knowledge and the human and financial resources to develop the necessary means to combat climate change. Recognizing the poverty that prevails among the populations of developing countries, it is natural that fight against poverty and achieving economic growth is given priority by them. Closing the gap between the industrialized and the developing countries is a prerequisite for a full partnership of all nations of the world in the development of a strategy to deal with the climate change issue.

A rapidly increasing world population will mean greater demands for resources in general and energy in particular. Management of the world's natural resources is also closely linked to the climate change issue. It is obvious, that all these and other global issues have to be addressed simultaneously.

Climate change issue is a long term, evolutionary issue. We are not able to foresee its long term consequences very well yet and will not be able to do so soon. However, scientific data indicate that at present the atmospheric concentrations of carbon dioxide and methane are on their way to reaching values well outside the range that has prevailed for more than 100,000 years. It seems prudent, then, to consider that an unlimited growth in the concentrations of greenhouse gases in the atmosphere is not acceptable. Although stabilization of the greenhouse gas concentrations in the atmosphere is ultimately a necessity, we cannot as yet determine at what levels they should be stabilized or the costs of such stabilization.

The discussions in Working Group III show that the difficulties in assessing the social and economic costs of climate change, as well as the consequences of the measures required to slow and ultimately

58 [illegible] slow and ultimately stop such a change, present us with serious difficulties when trying to develop a strategy to [illegible] measures

deal with the greenhouse gas issue. An obvious reason is that we cannot as yet predict reliably enough how a change of climate would influence different countries directly. On the other hand, the implications and particularly the costs, of the specific actions that are being considered to slow down or prevent a change of climate can be envisaged more easily by economists and politicians. Yet, it is not evident that more stringent and therefore costly measures would find approval amongst a broad majority of people even in countries where they may be reasonably well informed about environmental problems.

International agreements are necessary in order to have a balanced development of the world economy and to safeguard at the same time the global environment. This applies particularly when confronted with as complex an issue as that of climate change. If individual countries can optimize their benefits by letting other countries share their costs (i.e. pay for pollution) without they themselves taking the necessary precautions (reducing pollution), the economy of the total system becomes unstable and a catastrophic development may occur ("the law of the commons"). We must also recognize the vast differences in economic strength between the players on the international scene, i.e., the nations and the large multinational companies in the world. The fundamental question becomes: How can a sustainable and improving future for the developing countries i.e., for three quarters of humanity, as well as for the industrial countries, be achieved faced with the potential threat of climate change?

It is also clear that the effects of specific preventive actions being considered on the countries of the world vary much from one to another. At present fossil fuels account for 80 - 85% of the primary energy supply in the world, but different countries are very differently dependent on their use. Producers and users of fossil fuels will experience restrictions on the emissions of carbon dioxide into the atmosphere very differently.

Many developing countries have extensive plans of using fossil fuels for meeting their increased energy demands for development. The infrastructure of most countries to a large extent has been based on a fossil-fuel driven transport system.

Deforestation is in part an expression of the need to expand agriculture or the dependance on forest products for export. Measures to limit methane production in wet-land agriculture may imply major changes of traditional management practices with unpredictable consequences for the farmers involved. Any plan for combatting man-induced climate change must carefully consider these and many other concerns that will be faced by the world's countries. As a matter of fact, it is not surprising that controversies arise about as complex an issue as the present one, in particular when the detailed understanding of the likely problems is as yet incomplete. The major dilemma is that actions may be required well before many of these specific issues can be resolved.

Elements of a strategy and an action programme

The complexity of the problem as outlined above based on the detailed reports of the IPCC Working Groups, means that agreements on necessary actions will not be easy to reach. Working Group I has concluded that "the longer emissions continue to increase at present day rates, the greater reductions would have to be for concentrations to stabilize at a given level".

The IPCC emphasizes that despite scientific uncertainties [illegible] and timing of climate change, but because of the very long response times of the atmosphere, climate and society, it would be prudent to initiate negotiations on a framework convention on climate change as soon as possible.

First we address actions that could be taken now.

It is clear from the Working Group III report that there are a number of actions that also would be beneficial for other environmental reasons and that would cost comparatively little, as a matter of fact in some cases rather imply savings. These deserve attention now. An action program to take advantage of such possibilities has been called a "no regrets policy" defined as a policy of taking "measures in the shorter term which while helping to tackle climate change also can yield other benefits". Numerous measures of this kind have been considered by the Working Group III and are summarized in a previous section of this overview.

IPCC confirms that such measures would, if widely used, significantlky slow down the further increase of greenhouse concentrations in the atmosphere. These measures to be taken at the national, regional and international levels include:

* CFC controls to include resticted use of greenhouse active alternatives,
* use of energy sources with lower emissions of greenhouse gases,
* improved energy end use efficiency,
* improved forest management and where feasible expansion of forest areas,
* review of agricultural practices aiming at reduced greenhouse gas emissions.

More elaborate descriptions of these are given in earlier sections of this report.

IPCC further believes that individual nations, or groups of nations, should consider actions to stabilize emnissions in order to reduce the rate of increase in global emissions and thus assist in the prevention of an acceleration of greenhouse gas concentrations in the atmosphere. Such initiatives may accelerate progress towards international agreements.

Secondly, we address the need for a phased strategy for the longer term.

Awaiting the outcome of negotiations for general agreements on a convention, it is important [illegible]

Because existing information is inadequate to understand what rate of change of climate, and of greenhouse gas emissions, might be acceptable, there is a need for a phased approach. The first step would be to set criteria.

The IPCC considers that work should begin on definingcriteria which would reflect the impacts of climate change and their costs on the one hand, and the costs and practicalities of reductions in emissions on the other. Such criteria would be evolutionary; they should take into account what might be an acceptable level of climate change and reflect the changes in our scientific and economic understanding and technological capabilities.

In the light of the importance of understanding better the economics of the greenhouse gas issue,

the IPCC recommends that research on the international economic implications of the global climate issue be intensified, with particular regard to the specific circumstances of individual countries as well as the broad generic differences between developed and developing countries. Governments may consider developing mechanisms by which the international market can find optimal means to recognize the implicit climate change cost of human activities without hampering sustainable development, and in this regard, should fully evaluate economic consequences of such mechanisms.

Working Group III also emphasizes in this context the importance of public information and education.

IPCC supports the view that because climate change would affect, either directly or indirectly, almost every sector of society, and also because important policy responses will have to be developed against a background of uncertainty, broad global understanding of the issue will facilitate the adoption and the implementation of such response options as deemed necessary and appropriate. Further efforts to achieve this are urgently needed.

The Special Circumstances of the Developing Countries

It is obvious that the impact on and the participation by the developing countries in the further development of a future strategy is essential. The IPCC has addressed this specific issue by establishing a Special Committee on the Participation of Developing Countries. This subsection summarizes the findings on the issue.

Although emissions of greenhouse gases are increasing in developing countries, where about 75% of the world population lives, they emit only about 25% of the world total. Their per capita emission is only about a tenth of that in the industrialized world.

Industrialized countries and developing countries have a common responsibility in dealing with the adverse effects of climate change, taking into account not only the past and present responsibility of the industrialized world in the accumulation of greenhouse gases but also the present technological, human and financial capacities of the developed countries. An acceptable standard of living in the developing countries needs to be achieved before a developing country can be expected to participate fully in addressing issues related to climate chnage. In this context,

a) Industrialized countries should take the lead and have specific responsibilities on two levels;

i) To adopt domestic measures to limit greenhouse gas emissions by adapting their own economies in line with relevant future international agreements;

ii) To cooperate with developing countries in international action without standing in the way of the latter's development by contributing additional financial resources, by appropriate transfer of technology, by engaging in close cooperation concerning scientific observation, by analysis and research, and finally by means of technical cooperation geared to forestalling and managing environmental problems;

b) Emissions from developing countries are growing and need to grow in order to meet their development requirements. Thus, over time, they are likely to represent an increasingly significant percentage of global emissions. Developing countries should, within the limits feasible, take measures to suitably adapt their economies.

Against this background, IPCC requested its Special Committee to identify factors inhibiting the full participation of the developing countries in IPCC and recommend remedial measures where possible. The Committee stresses that full participation includes not only the physical presence at meetings but also the development of national competence to address all issues of concern such as the appreciation of the scientific basis of climate change, the potential impacts on society of

The factors identified by the Special Committee are:

*insufficient information;
*insufficient communication;
*limited human resources;
*institutional difficulties;
*limited financial resources.

On some of these factors, the IPCC Working Groups have developed policy options which are to be found in their respective reports. The Special Committee itself has made a number of specific recommendations including the development of specific programmes of action; these are to be found in its report. The implementation of the recommendations and appropriate policy options will require commitment of financial resources and mechanisms.

Financial resources channelled to developing countries would be most effective if focused on those activities which contribute both to limiting greenhouse gas emissions and/or adapting to any adverse effects of climate change, and promoting economic development. Areas for cooperation and assistance could include:

- Efficient use of energy resources and the increased use of fossil fuels with lower greenhouse gas emission rate or non-fossil sources;
- Rational forest management practices and agricultural techniques which reduce greenhouse gas emissions;
- Facilitating technology transfer and technology development;
- Measures which enhance the capacity of developing countries to develop programs to address climate change, including research and development activities and public awareness and education;
- Participation by developing countries in international fora on global climate change, such as the IPCC.

It was recognized that cooperation and assistance for adaptive measures would be required, noting that for some regions and countries, adaptation rather than limitation activities are potentially most important.

The IPCC concludes that the recommendations of the Special Committee need not and should not await the outcome of future negotiations on a climate convention. It appeals to the multilateral and bilateral funding organizations to implement the recommendations. It further appeals to the governments for continuing and increased contributions to the IPCC Trust Fund on an urgent basis.

ANALYSIS AND PERSPECTIVE

GLOBAL CLIMATE CHANGE: A RETROSPECTIVE VIEW FROM BUSINESS

by Thomas G. Lambrix

Introduction

I have heard it said that global climate change is the "super tanker" of environmental issues. It has all the characteristics of becoming the foremost environmental crusade of the 1990s and well into the next century. In fact, some would argue that it already *is* the principal environmental concern facing all nations of the world today. That is because the ecological implications from a future that is significantly or even moderately warmer than today are potentially substantial, perhaps resulting in incredible changes to our physical world. These changes, should they occur, would also manifest themselves in economic as well as societal impacts that are hard to quantify, but would undoubtedly be dramatic.

However, understanding and attempting to describe future global climate change is perhaps one of the most challenging undertakings that our modern scientific community will face because attempting to understand the world's climate involves grasping the innumerable interactive and complex variables that make up our global environment.

The political dimensions of global climate change are also extremely complex. Nations look at this issue differently—some with more concern than others, and some who support responses that are more radical than others. As for the United States, our citizens have for the past year and a half been shown an array of stories from the print and visual media describing a whole range of possible impacts associated with global climate change. They have heard from scientists, government representatives, and leaders in environmental groups. As a result, people have become aware and many are anxious over what global warming means for them and their children. While an informed public is desirable, in my opinion most of this concern has been focused on the more pessimistic impact scenarios that have been given visibility by the popular press.

Dr. Patrick Michaels, a climatologist from the University of Virginia recently noted, "...*Time Magazine* painted the following picture in its 1988 'Man of the Year' issue, featuring Planet Earth: If left unchecked, anthropogenerated alterations of the atmosphere will bring, by the years 2030-2050, a global temperature rise of 4°C, ecological chaos including famine, related civil strife, and tidal waves crashing through a Manhattan landscaped with palm trees...."

Dr. Michaels continues, "Such scenarios also abound in the writings of politically active environmental scientists, environmental lobbyists, and newswriters. United States elected officials have compared the current situation to that of fascist Germany, where several events, such as Kristallnacht, presaged the holocaust. Those that do not recognize this have been labeled modern-day Neville Chamberlains. Draconian interventionist legislation has been proposed and the implementation of 'global warming' is now a touchstone of U.S. foreign policy. Clearly, deep emotional commitments now guide this issue."[1]

While there has been considerable attention to these views, little public scrutiny has so far been given to what it might mean to adjust lifestyles and otherwise pay for corrective measures here and around the world to address global climate change. So, while the issue has been "teed up," awaiting action for some months, its full dimensions still remain unclear, and consensus on solutions is elusive. As I have said, global climate change is the super tanker environmental issue; it can potentially affect our values, our behavior, our social structures, and our institutions, which, like a super tanker, are slow to form, slow to stop, and slow to change. All of this, from the science to the politics, is incredibly complex.

In commenting on this notion recently, Dr. Allan Bromley, President Bush's Science Advisor, drew this humorous anecdote: "In considering the challenge of understanding global change, it is easy to sympathize with the remark of the medieval king Alfonso X of Castile, who said, 'If the Lord Almighty had consulted me before embarking on the Creation, I would have recommended something simpler.' "[2]

It is within this context that U.S. industry wants to be an active and constructive participant in offering reasoned and responsible actions to address this aspect of Alfonso's dilemma.

The Global Climate Coalition

Earlier this century, U.S. President Calvin Coolidge announced, "The chief business of America is business." Today, promoting economic growth through private enterprise remains a chief business of America, although there is a maturity to business actions that bear distinction. Businesses today recognize the need to not only make a profit and to enhance shareholder value, but to be responsible corporate citizens that are concerned about the quality of lives in America and around the world.

This has especially been true over the last 20 years as businesses have invested in environmental quality, corporate philanthropy, education, drug abuse prevention, and other worthy social programs.

I think today business recognizes that it must be accurately perceived by the public as pursuing an agenda that is in harmony with society's goals. Particularly, managers

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of U.S. industries appreciate that citizens will no longer tolerate poor environmental quality, even in the name of absolute economic progress.

Businesses today spend many billions annually for environmental protection measures, and businesses recognize that more investments will be required. And, these investments have paid off in demonstrable improvement to U.S. environmental quality.

So in approaching this complex question of potential changes to our global climate, businesses in this country have taken an active interest. The Global Climate Coalition is a result of that interest. It it an ad hoc organization of a broad spectrum of U.S. companies and trade organizations representing energy consumption, energy production, information, and allied industries.

Our involvement is premised upon the seriousness with which we view this issue and on the potentially enormous impact certain suggested resolutions of the issues may have on our industrial base and the national economy. For the past year, the Coalition has embarked on programs to encourage scientific research, reviewed voluntary initiatives that can be adopted, participated in governmental review of the issue both here and abroad, provided economic analysis, and otherwise promoted informed debate of policy responses.

Need For Science

When it has come to supporting new government laws and regulations to deal with environmental matters, business has often been criticized for its opposition to new legislative proposals. At a minimum, business has been seen as a reluctant partner in achieving solutions. Often business has been seen by others to be hiding behind a position of "more study." Critics see this stance as one of delay, where businesses hope the problem will go away.

I am beginning to hear this comment directed toward business on global climate change, and I expect we will hear it again as the debate continues. This is unfortunate, because I believe it is only natural for businesses to be interested in obtaining as many facts as possible about a problem before acting.

This does not equate to a lessening of concern, but to a posture of responsible action. In everyday matters, business carefully pursues a study of data and options before making investments. This is the nature of business. And in the case of global climate change, despite the criticisms and the emotional appeal for drastic action, *more study is required.*

Most readers are familiar with the outstanding disagreements, questions, and uncertainties regarding the scientific basis for anthropogenically generated global climate change. We believe that, while there is no disagreement over the "greenhouse" theory itself and that atmospheric accumulations of greenhouse gases are increasing, there are differing views over the significance of future greenhouse gas emissions and whether and what should be done about it now.

For example, at a recent meeting of climatologists hosted by the National Academy of Sciences, a group of nationally recognized climate experts generally agreed that emerging evidence has reduced expected global warming (responding to a carbon dioxide doubling) to about 2° Celsius.[3] This is at the low end of the scale from the predictions that were publicized only a year ago.

In addition, *The Washington Post* recently reported, "According to Mark Meier of the Institute of Arctic and Alpine Research at the University of Colorado, the consensus now is that sea level will rise by about a foot in the next century, rather than the three feet that had been suggested in previous studies."[4]

Even Dr. Stephen H. Schneider, the National Center for Atmospheric Research (NCAR) climatologist who has publicly stated a personal bias for moving ahead with policies to slow down the rapid buildup of greenhouse gases, wrote recently, "The consensus about the likelihood of future global change weakens over detailed assessments of the precise timing and geographic distribution of potential effects and crumbles over the value question of whether present information is sufficient to generate a societal response stronger than more scientific research on the problems...."[5]

It is, therefore, our opinion that enhanced scientific research should be our first priority. We should be focusing significant resources to reducing as much of the scientific uncertainty as possible over the next 10 to 20 years. Clearly, enhanced effort will be required but we believe this is a necessary and sound investment.

Again, quoting Dr. Schneider, "... A dedicated effort to accelerate the rate of progress could conceivably speed up the establishment of a consensus on regional issues, but at best 10 years or so will be necessary even with a dramatic effort. *However, such efforts would clearly put future decision making on a firmer factual basis and help to make adaptation strategies more effective sooner.*"[6] (emphasis added)

That is why the Coalition supports the U.S. government's efforts that are being undertaken by the Committee on Earth Sciences and believes it should move forward with all speed. The Coalition enthusiastically endorses President George Bush's call for substantially increasing federal funding next year for research devoted to all aspects of global climate change. In addition, we strongly believe that government and industry should work together in accomplishing our research goals.

We should make every effort to remove any barriers to a greater working relationship between government and industry and identify specific opportunities for forming joint industry/government partnerships.

We recommend, specifically, that the U.S. focus its research on analytic efforts to establish the relative integrity of our general circulation models; on understanding the dynamics of the carbon cycle; on sorting out the respective roles of cloud formation, the oceans, and volcanic activity; and developing reliable regional effects and, importantly, on differentiating between real climate changes due to the normal variations of natural climatic phenomena and qualified changes attributable to anthropogenically-generated gases.

While the Coalition firmly believes that additional scientific understanding is necessary, it is important not to leave the conclusion that we are just hiding behind th

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nore study" solution to this problem. This is not an ccurate representation.

Coalition's Agenda

The Coalition is also vigorously pursuing the follow-ıg agendas:

• Support for international leadership. The Global Cli-ıate Coalition strongly supports leadership by the United tates toward developing a responsible approach interna-onally to the global climate change question.

Here we believe it is important that the U.S. govern-nent exercise this leadership through its chairmanship of he response strategies working group of the Intergovern-nental Panel on Climate Change (IPCC) and through the llocation of its financial resources toward cooperative fforts here and abroad to address scientific, economic, nd technical questions.

The Coalition has met with various members of the PCC's U.S. delegation, from the Environmental Protec-ion Agency, and the departments of State, Energy, Com-nerce, and Interior. The Coalition also recognizes and supports the efforts of the many other countries, their ndustries, and non-government organizations involved in he IPCC process.

I believe that there is little disagreement among inter-ested parties over the premise that unilateral action by any one nation will not have a meaningful impact on the accumulation of greenhouse gases in our atmosphere.

In fact, while North America and the industrialized nations of the world have been and are today the major contributors to anthropogenic atmospheric greenhouse gas buildup, this trend is declining and will reverse itself in the future when the developing world becomes the significant contributor.

The cooperation and active input from the developing countries will be essential for an effective global response to potential global warming.

In a report that the Global Climate Coalition commissioned last year to evaluate some of the economic implications of unilateral action on global warming, the Washington-based Center for Strategic and International Studies reaffirmed the importance of this conclusion.

It stated, "The world's population is expected to grow from 5 billion in 1988 to 6 billion in the year 2000 and 8 billion by 2025. Most of this increase will be in the Third World and the communist nations where energy demand has doubled since 1971. Almost all of this increase has been in fossil fuels."

Developing countries are expected to quadruple their energy consumption between now and the year 2025. By the middle of the next century, they will account for the bulk of the greenhouse gases emitted into the atmosphere, even if they succeed in doubling their energy efficiency."[7]

Therefore, the industrialized countries must obtain the cooperation and active input from the developing countries for an effective global response to potential global warming. The challenge to companies and policymakers here and abroad is to work with these nations as they strive to improve the standard of living for their expanding populations and do so in a way that promotes economic growth and is sustainable to the environment, including the global atmosphere. I am confident that U.S. businesses will be anxious to help.

• Support for initiatives. At home, the Coalition supports strong leadership by the president and the U.S. Congress on global climate change. We particularly support the president's endorsement of a free-market approach toward identifying appropriate responses. We also agree with the president that intervention action by the United States unilaterally in the economy is not warranted at this time.

This does not mean that other activities cannot be pursued. For example, in addition to supporting the president's announced program for enhanced scientific research, the Coalition enthusiastically supports investments in cost-effective energy efficiency, orderly phase-out of chlorofluorocarbons, development of public education programs, and implementation of reforestation initiatives.

In addition, we believe there are other opportunities to demonstrate presidential and congressional leadership. I will mention just two specific programs. The first is the announcement of a federal demonstration program for energy efficiency and renewable energy technologies. The U.S. government should lead by example by investing in energy efficiency applications in the federal estate. This should both help educate the public at large about the application of these technologies and also reduce production costs.

Second, the president should announce a "Nationwide Recognition Program" designed to identify and reward citizen efforts and investments in such areas as new energy efficiency technologies; school education programs, including scholarship awards for science and related subjects; and community efforts such as recycling and reforestation programs.

Towns and villages in the United States could "adopt a town" in another country and set up information and assistance exchanges to emphasize local actions by citizens around the globe. The president could instruct the chairman of his Council on Environmental Quality, in cooperation with other appropriate agencies, to develop and implement this program. A congressional joint resolution to this effect would also be welcome. Companies could set up parallel programs, and, in fact, many companies are already undertaking specific steps on their own.

In an address to a recent meeting of the National Governors Association, Secretary of State James Baker discussed the president's program to address global climate change. He described this program as a "no regrets policy." He explained that the administration was prepared to take actions that are "...fully justified in their own right *and* which have the added advantage of coping with greenhouse gases."[8]

The Coalition supports this approach to policy making on global climate change and recognizes that business has a responsibility for developing constructive responses. In order to establish itself as a credible, informed, and committed partner in the search for appropriate responses, business must increase its efforts to make environmental conscientiousness a matter of routine practice and con-

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tinue to accelerate its own efforts to invest in cost-effective energy efficiency technologies.

Coalition member companies have accrued almost 20 years of research and technological experience in the pursuit of cost- effective energy efficiencies which equally serve sound economic and environmental policy. We believe we are making progress, and we intend to continue to look for ways to increase efficiency and reduce pollution. In the future we hope that any improvements we develop here can be made available around the world.

At this time, the Global Climate Coalition is actively investigating a menu of industry initiatives that can be supported now, that make sense in their own right by providing cost-effective investments, and that also do not aggravate the buildup of greenhouse gases.

Voluntary industry adoption of specific programs now could include energy efficiency technologies, productivity increases, development of new products and technologies, waste minimization, and identification of innovative programs to disseminate technology and deal with the real problems of technology transfer from the developed to the developing world.

The point to stress here, I believe, is that it is critically important that the U.S. government's policy should encourage business to take these steps by creating a favorable climate. This means that our policy should rely heavily on free market principles and the application of incentives *rather* than the institution of penalties, if the private sector is to be most effective in responding.

We need to stress flexibility in our energy, agricultural, foreign assistance, and research policies so that we can adjust our programs and our investments as our understanding of the global climate change phenomenon increases and as our multilateral discussions mature.

We are pleased to see that President Bush supports this emphasis as well. As he stated in his remarks recently to the IPCC, "If we hope to promote environmental protection and economic growth around the world, it will be important not to work in conflict, but with our industrial sectors. That will mean moving beyond the practice of command, control, and compliance—toward a new kind of environmental cooperation...."[9]

Conclusion

Global climate change has now achieved high visibility on the environmental/political agendas of all of the industrialized nations of the world and many of the developing nations. This has occurred in essence over a period of less than two to three years, a very rapid pace. The result is an incredible upswell of political momentum that calls for "solutions," at a rate that has outpaced our understanding of the scientific causes of the phenomena and economic impacts of responses.

While scientific attention to the concern is widespread and will continue, science still lags behind the desires of politicians for assistance in drafting responses. Even though more recent scientific forecasts have lowered, not raised, the range of potential warming and ecological response, pressures continue for governments to do something now.

After a year and a half of intense public and political visibility to the projected ecological disasters caused by global climate change, we are only now beginning to address ourselves to the economic consequences of responses that some have touted as absolutely necessary to deal with this "crisis."

The question of who pays and who benefits will become the principal negotiating point of attention in the future as the United States and nations around the world determine economic and societal effects of mitigation and adaptation responses.

Here in the United States, I don't believe that we will continue to view global climate change in the same context as other environmental issues, such as enactment of new clean air legislation. The issue is too complex and the requirements on our citizens much more drastic if severe intervention strategies are implemented.

This point was specifically noted in a recent report by the Department of Energy, which concluded: "Unless ... there is uncontentious sustained evidence of climate-change impacts, a real possibility exists that the current appearance of societal consensus in favor of urgent action on climate change may fragment as the costs to various sectors of society become clear. Even if the resulting economic disruption and societal conflict can be overcome, such conflict carries its own costs which must be considered part of the true social cost of a policy package...."[10]

To address these important economic issues, the Coalition has retained a contractor team to undertake an economic assessment of potential near-term policy responses by the United States.

Specifically, the objectives of the study are to:

- Analyze the impact of proposed policy actions on the U.S. economy and on the competitiveness of U.S. industry in world markets;
- Determine the impact of proposed policy actions on net global greenhouse gas emissions; and
- Assess the geopolitical context of proposed policy actions by the United States.[11]

This project should be completed by late spring. Our hope is that the results of this study will further advance our understanding of the economic aspects of this issue. We intend to make the conclusions available to our policy-makers.

Many sectors of society, from academic think tanks, to environmental groups, to climatologists, to business, to government bureaucrats, to elected officials, to the press and media, generate information themselves and are being overwhelmed by others by a mass of materials advocating a full spectrum of views on this issue. Sorting out the tidbits of valuable information among the noise will be a real challenge. All of us need to be alert to other agendas and political motivations that will struggle and compete with each other to influence and drive the issue.

However, in spite of all the hype given to this issue, the notion of potential climate change brought about by global warming remains a serious issue. I am optimistic that we will see serious and balanced proposals crafted to understand and respond. As I have said, these proposals

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must be developed multi-nationally to be effective and must be based on sound science to be credible.

Companies are moving to adopt environmental principles of operation and to ensure that their businesses are compatible with the goals of society, including the goals for preserving and enhancing the quality of our environment. This trend will continue.

Business does not oppose action. But we object to acting in haste when the consequences can be enormous and the intended result ineffective. Business by necessity will look at responding to global climate change from the perspective of economic reality.

We want our actions to be supported by the science, and we need to understand the tradeoffs between benefits and costs. Again, as President Bush reminded the delegates to the IPCC, "Much remains to be done. Many questions remain to be answered. Together, we have a responsibility to ourselves and the generations to come to fulfill our stewardship obligations. But that responsibility demands that we do it right."[12]

There are rapid changes occurring in our global economic environment. Now more than ever, we live in a global economy. International competitiveness will be a preeminent factor in determining not only corporate, but national success. How our climate response strategies affect our competitiveness must be a major consideration.

Our view is that a strong economy will be necessary to provide the capital for investment in needed technology and for taxpayer-financed assistance to other nations. This last year alone has seen the demise of the centrally planned economic systems of Eastern Europe, as citizens of these nations cried out for freedom and a better life. They are now endorsing market-based economies. Our policies should stimulate the private sector's investments in these countries and in the developing world to both lift their economies and improve their environments.

I recently had the opportunity to listen to a speech by Dr. Carl Sagan, a Cornell University astronomer.[13] Dr. Sagan was giving an overview of the Voyager program as the satellite was nearing its approach to the planet Neptune, I recall Dr. Sagan praising the accomplishments of this project, indicating that Voyager had traveled to the outer limits of our solar system, achieved far more than its objectives, and was completing its mission on budget. Sagan indicated that it was a wonderful thing what technology could do when it was freed up to meet this formidable challenge.

We believe that given the same opportunity to unleash our creativity within free and strong economies, our nation and other nations of the world will likewise respond to the scientific and political challenges from global climate change.

NOTES

[1] Dr. Patrick J. Michaels, "The Greenhouse Effect and Global Change: Review and Reappraisal" to be published in *International Journal of Environmental Studies*, 1990.

[2] Dr. D. Allan Bromley, Address to a Conference on "Earth Observations and Global Change Decision Making: A National Partnership", sponsored by National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and Environmental Research Institute of Michigan; National Press Club, Washington, D.C., September 18, 1989, pp. 9-10.

[3] National Academy of Sciences, Panel on Policy Implications of Greenhouse Warming, Washington, D.C., Discussions of January 24, 1990.

[4] William Booth, "New Models Chill Some Predictions of Severely Overheated Earth", *The Washington Post*, January 29, 1990.

[5] Dr. Stephen H. Schneider, "The Greenhouse Effect: Science and Policy", *Science*, February 10, 1989, Vol. 243, p. 778.

[6] Ibid, p. 781.

[7] Center for Strategic and International Studies, A Report for the Global Climate Coalition, "Implications of Global Climate Policies", Washington, D.C. June 27, 1989.

[8] James A. Baker, III, "Diplomacy for the Environment" Presentation to the National Governors Association, February 26, 1990, pp. 5-6.

[9] President George Bush, Remarks to the Intergovernmental Panel on Climate Change, Washington, D.C., February 5, 1990, p. 3.

[10] U.S. Department of Energy, Report to the Congress of the United States, "A Compendium of Options for Government Policy to Encourage Private Sector Responses to Potential Climate Change", October 1989, Vol. 2, p. 12-4.

[11] The Global Climate Coalition has retained the team of the Center for Strategic & International Studies (CSIS), Putnam, Hayes & Bartlett, Inc. (PHB), the International Resources Group (IRG), The Brock Group, and DRI/McGraw-Hill to undertake an economic assessment of potential near-term policy responses by the United States in regard to reduction of emissions of greenhouse gases.

[12] President Bush, p. 3.

[13] Dr. Carl Sagan, Remarks to the Greenhouse Glasnost Conference, The Sundance Symposium on Global Climate Change; Institute for Resource Management/Soviet Academy of Sciences; Sundance, Utah, August 1989.

Thomas G. Lambrix is Director, Government Relations for Phillips Petroleum Company, and is chairman of the Global Climate Coalition. Mr. Lambrix has degrees from Rutgers University and the University of Massachusetts. Before assuming employment with Phillips, he worked for almost 10 years with the U.S. government, including positions at the U.S. Department of Interior and a presidential appointment to the White House Domestic Policy Staff. For a current listing of the Global Climate Coalition membership, please contact Mr. Lambrix at Phillips Petroleum Company, 16 D2 Phillips Building, Bartlesville, Oklahoma 74004.

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Global Climate Coalition Membership

Aluminum Association
American Electric Power Service Corporation
American Gas Association
American Iron & Steel Institute
American Mining Congress
American Nuclear Energy Council
American Paper Institute
American Petroleum Institute
Amoco Corporation
ARCO
Armco, Inc.
Arizona Public Service Company
Association of Home Appliance Manufacturers
AT&T
Automobile Importers of America
BHP - Utah Minerals International, Inc.
Business Roundtable
Champion International
Chemical Manufacturers Association
Chevron U.S.A., Inc.
Chrysler Corporation
Coalition Opposed to Energy Taxes
Consolidation Coal Company
Consumers Power Company
Council of Industrial Boiler Owners
Dow Chemical Company
E.I. Dupont de Nemours & Company, Inc.
Eastman Kodak
Edison Electric Institute
Electricity Consumers Resource Council
Entergy Corporation
Ford Motor Company
Fusion Power Associates
General Motors Corporation
Georgia Pacific Corporation
Hercules Incorporated
IBM
Illinois Power Company
Int'l Business-Government Counsellors, Inc.
Jefferson Energy Foundation
Kaiser Aluminum & Chemical Corporation
Maytag Corporation
Monsanto Company
Motor Vehicle Manufacturers Association
National Association of Manufacturers
National Coal Association
National Steel Corporation
Occidental Chemical Corporation
Pacific Gas & Electric Company
Peabody Holding Company, Inc.
Pennsylvania Power & Light Company
Petrochemical Energy Group
Petroleum Marketers Association of America
Phillips Petroleum Company
Portland Cement Association
PPG Industries
Process Gas Consumers Group
Public Service Indiana
Rubber Manufacturers Association
Shell Oil Company
Society of the Plastics Industry, Inc.
Southern Company Services, Inc.
Texaco, Inc.
Union Carbide Corporation
UNOCAL Corporation
U.S. Chamber of Commerce
U.S. Council for Energy Awareness
U.S. Council for International Business

May 8, 1990

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
02. Memo	From James Watkins to John Sununu Re: Domestic Policy Council (2 pp.)	7/10/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: Global Warming 1990 (1 of 2) [3]

Open on Expiration of PRA
(Document Follows)
By JP (NLGB) on 1/19/09

Date Closed:	12/20/2004	**OA/ID Number:**	29157-003
FOIA/SYS Case #:	1998-0004-F[1]	**Appeal Case #:**	
Re-review Case #:	2005-0426-S	**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
AR Case #:		**MR Case #:**	
AR Disposition:		**MR Disposition:**	
AR Disposition Date:		**MR Disposition Date:**	

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The Secretary of Energy
Washington, DC 20585

July 10, 1990

MEMORANDUM FOR: The Honorable John H. Sununu
The Chief of Staff
The White House

FROM: James D. Watkins
Secretary of Energy

SUBJECT: Domestic Policy Council
Direction in Global Climate

John:

In the next few months, there will be a flurry of international meetings to discuss responses to global warming. These include the Fourth Plenary Intergovernmental Panel on Climate Change (IPCC) meeting in late August, the Second World Climate Conference in late October and early November and the commencement of framework convention negotiations later this year or early next year. Preparing for these meetings must be made a major priority of the Administration.

There is no time to lose. By the end of July, we will need a fully considered U.S. Government position on the IPCC Final Report on Global Climate Change. As you know, John, the U.S. has placed heavy reliance on the IPCC work. This "policymakers' summary" is crucial. It is all anyone will ever read. It will be a primary agenda item for the Second World Climate Conference and will be the foundation for the framework convention negotiations.

I believe that the U.S. position on global climate change is not being adequately reflected in the IPCC Summary Report. Nor does the Summary Report accurately reflect the results of the scientific research reported in the base document. Currently DOE and other agency staff are reviewing the document and supplying line-by-line comments to the State Department. However, there appears to me to be no overall U.S. strategy for the IPCC plenary meeting in August and the follow-on meetings. We still do not seem to have an agenda. Instead, we are reacting, fighting off proposals that advocate immediate action on targets and timeframes for reducing CO2. As you know, the potential implications to the U.S. economy of adopting premature commitments such as this are tremendous.

We need a better game plan for coordination and development of a U.S. strategy on global climate. Please consider the following:

- o A reaffirmation of the Administration's climate change policy to help assure that we have a strategy that clearly supports this policy. I believe we have a sound policy which needs to be articulated in a positive way.

- o We need more White House guidance and control of the decisionmaking process. I would propose that decisions regarding global climate change policy should be made only after deliberations by the Domestic Policy Council.

- o The DPC should focus on a two-year horizon, coinciding with the 1992 U.N. Conference on Environment and Development. More specifically, we need a comprehensive strategy that anticipates the Fourth IPCC Plenary meeting, the negotiations on a climate change framework convention, and carries us out to the 1992 U.N. Conference, where a framework convention will be signed.

- o Additionally, after the establishment of our policies and positions, we must begin to articulate our posture through the preparation of our draft Ministerial declarations, executive summaries and other international documents. We need to stop merely reacting to other countries' documents and start getting our own positions on the table, early.

I believe that you share my view that we stand at a critical juncture in the global climate change debate. I am convinced that your active personal involvement is essential if we are to succeed in managing this issue properly. I recommend that you chair a special committee of the DPC on developing a long-term strategy on global climate change. We are prepared to commit whatever resources are necessary to assist you in this effort.

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
03. Memo	From D. Allan Bromley to John Sununu Forthcoming IPCC Plenary Session in Sweden (2 pp.)	7/12/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: Global Warming 1990 (1 of 2) [3]

Open on Expiration of PRA
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By JP (NLGB) on 10/28/05

Date Closed:	12/20/2004	**OA/ID Number:**	29157-003
FOIA/SYS Case #:	1998-0004-F[1]	**Appeal Case #:**	
Re-review Case #:	2005-0426-S	**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
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THE WHITE HOUSE

WASHINGTON

July 12, 1990

MEMORANDUM FOR JOHN H. SUNUNU

FROM: D. ALLAN BROMLEY

SUBJECT: FORTHCOMING IPCC PLENARY SESSION IN SWEDEN

As you know, the final plenary session in the first round of activities of the IPCC is scheduled to take place in Sweden in early August. This memorandum is intended as a heads up concerning aspects of U.S. participation in that meeting.

Fred Bernthal, as Deputy Director of NSF, recognizes that the meeting coincides with Erich Bloch's last week on the job as Director of NSF and feels that he should be in place at NSF. In my discussions with him, however, he has agreed that if it is felt that his services are required in Sweden, he would be reluctantly willing to go and perform his swan song as Chairman of Working Group #3. I believe that it is important that he be present because otherwise we will have very little continuity with the discussions that have led up to this final meeting and very little effective input toward affecting the report that emerges from it. In his absence, also, we in the U.S. will have little chance of holding the chairmanship of this Working Group.

John Knauss, the Director of NOAA, called me to volunteer to head up the U.S. Delegation to the Swedish meeting but in order to make plans for the latter part of the summer, he requests that he be told as soon as possible whether he should plan on attending. Here again I think it is important for John to attend because he brings an extensive technical background to the discussions and in that role can complement Bernthal.

Finally, Bill Reilly has urged that Buff Bohlen, who has now been confirmed as Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, be named as Bernthal's replacement as Chairman of Working Group #3, if, as seems probable, that Working Group and the entire IPCC structure continues to function after the forthcoming plenary. Unfortunately, although Bohlen has extensive experience in other aspects of international environmental matters, he has had very little contact thus far with the global climate change question and in particular, has had no contact whatsoever with the detailed IPCC discussions.

My recommendation to you would be that Bernthal, Knauss, and Bohlen should all attend this IPCC plenary; Bernthal, to wind up his activities and make sure that U.S. views are properly represented in the closing discussions leading to the final IPCC report; John Knauss, because of his technical competence and because I believe that he would be the logical replacement for Bernthal as Chairman of Working Group #3 if it continues and if, indeed, the U.S. is allowed to retain its chairmanship--something that is far from certain at this point. Finally, Buff Bohlen, to give him an opportunity to become acquainted with some of the issues, meet some of the people and become sensitized to some of the very important political undercurrents that are conditioning activities in the global change area.

I would have some concern about naming Bohlen to the working group chairmanship if we are given the opportunity to name the chairman at least until he has had considerably more exposure to this whole international area, but I am quite prepared to admit that, after some decent interval and with such exposure, he might well be an appropriate person to replace John Knauss, if such replacement were deemed desirable. Knauss is not an accomplished chairman although a great scientist and I am told that Bohlen has demonstated very real abiality in running meetings--both national and internationally--very effectively.

Finally, I would welcome an opportunity, at your convenience, to discuss with you what role you see in the future for the DPC Working Group on Global Climate Change.

SCIENTIFIC AMERICAN July 1990 Volume 263 Number 1

The Great Climate Debate

Greenhouse effect and the prospect of global warming is the subject of scientific and political controversy. Should we take steps now to avoid consequences we cannot foresee?

by Robert M. White

In the waning years of the 10th century, millions braced themselves for the apocalypse, believing that the approaching year 1000 was the very millennium—the end of the heavens and the earth prophesied in the Bible's Book of Revelation. Not surprisingly, the prospect of the impending Day of Wrath terrified normally sane people into rash and (in retrospect) foolish actions. Some gave away all of their possessions; others hastened to do harsh penance for their deeds.

In this final decade of the 20th century, a different kind of apocalypse causes widespread concern. This time the hand of God has been replaced by more visible agents: belching smokestacks, gasoline-powered automobiles, power-generating stations and the voracious destruction of forests, all of which may be turning up the heat on an overburdened environment. Global climate warming, some claim, threatens the very habitability of the planet. Others hold that the predictions of environmental collapse are not well founded and are goading us into hasty political action. Is our planet the "Endangered Earth," as *Time* magazine would have it in its 1988 year-end cover story? Or is it as *Forbes* magazine put it, "The Global Warming Panic: A Classic Case of Overreaction"?

Debate in the media reflects uncertainty among climatologists and geophysicists. Some of the world's eminent authorities on the atmosphere recently hurled verbal brickbats at one another in the pages of the prestigious journal *Science*. Their charges of "junk science" and "science by consensus" reflect the acrimonious nature of the debate within the scientific community. Some members of the National Academy of Sciences, including one of its former presidents, charge that policymakers are being induced to take unwise actions on the basis of uncertain scientific evidence. Set against this view is the recent statement of the Union of Concerned Scientists urging action by the government. It was signed by 52 Nobel laureates and more than 700 members of the NAS.

In spite of the scientific uncertainty, government and nongovernment groups are rushing to outdo one another in urging drastic action now to "stabilize" the global climate. From Washington to Toronto and The Hague, from Cairo to Moscow, international conferences of experts and political leaders have called for action. Soviet President Mikhail S. Gorbachev, President George Bush, British Prime Minister Margaret Thatcher and French President François Mitterand share similar views on the climate-warming issue.

Back home, debate within the Bush administration on how the U.S. government should act is intense. Caught between the urgings for action from the Environmental Protection Agency and Congress and cautions from his science adviser and chief of staff, President Bush called two major conferences to address the issue of climate warming. The first, held in April, brought together the heads of scientific, economic and environmental agencies of many governments. The second will be an initial meeting of governments, scheduled for early 1991, to begin negotiation of an international convention to stabilize global climate.

While there are still doubts in the White House, Congress has been environmentally hyperactive. Many pieces of legislation have been introduced to address the predicted climate warming. Leading the bipartisan effort have been Senator Timothy E. Wirth of Colorado, Senator Al Gore of Tennessee and Congresswoman Claudine Schneider of Rhode Island. Some of this legislation is comprehensive and far-reaching. It offers suggestions for action on the energy, agriculture and transportation fronts as well as for intensified research.

The actions proposed would radically change the most vital functions of human economies. They could include such diverse actions as using energy more efficiently, shifting the fossil-fuel mix from oil and coal to natural gas, relying more heavily on renewable energy sources and using more nuclear and solar energy. Measures could also include implementing reforestation, phasing out use of chlorofluorocarbons (CFC's) and changing agricultural practices.

Policy initiatives of this kind would

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alter the technology and economics of energy. Our use of land and water would also need to change. Economic growth in nations dependent on fossil fuels might be slowed. And the problems of arresting the growth of global population would become even more pressing. How can national and international policy formulation be moving so rapidly to address the specter of climate warming when agreement about the science is lacking and the economic and social costs of action have hardly been tallied? At the root of this thinking is a confluence of diverse scientific, economic and environmental forces.

The idea that the actions of humanity might change the composition of the atmosphere and hence the world's climate has deep historical roots. As early as the 1860's, it was suggested that slight changes in atmospheric composition might bring about major variations in climate. Increases in carbon dioxide (CO_2) and other atmospheric trace gases can contribute to what has been called greenhouse warming because these compounds allow the sun's energy to reach the surface of the earth, thereby warming it, while preventing much of that energy from being reradiated to outer space.

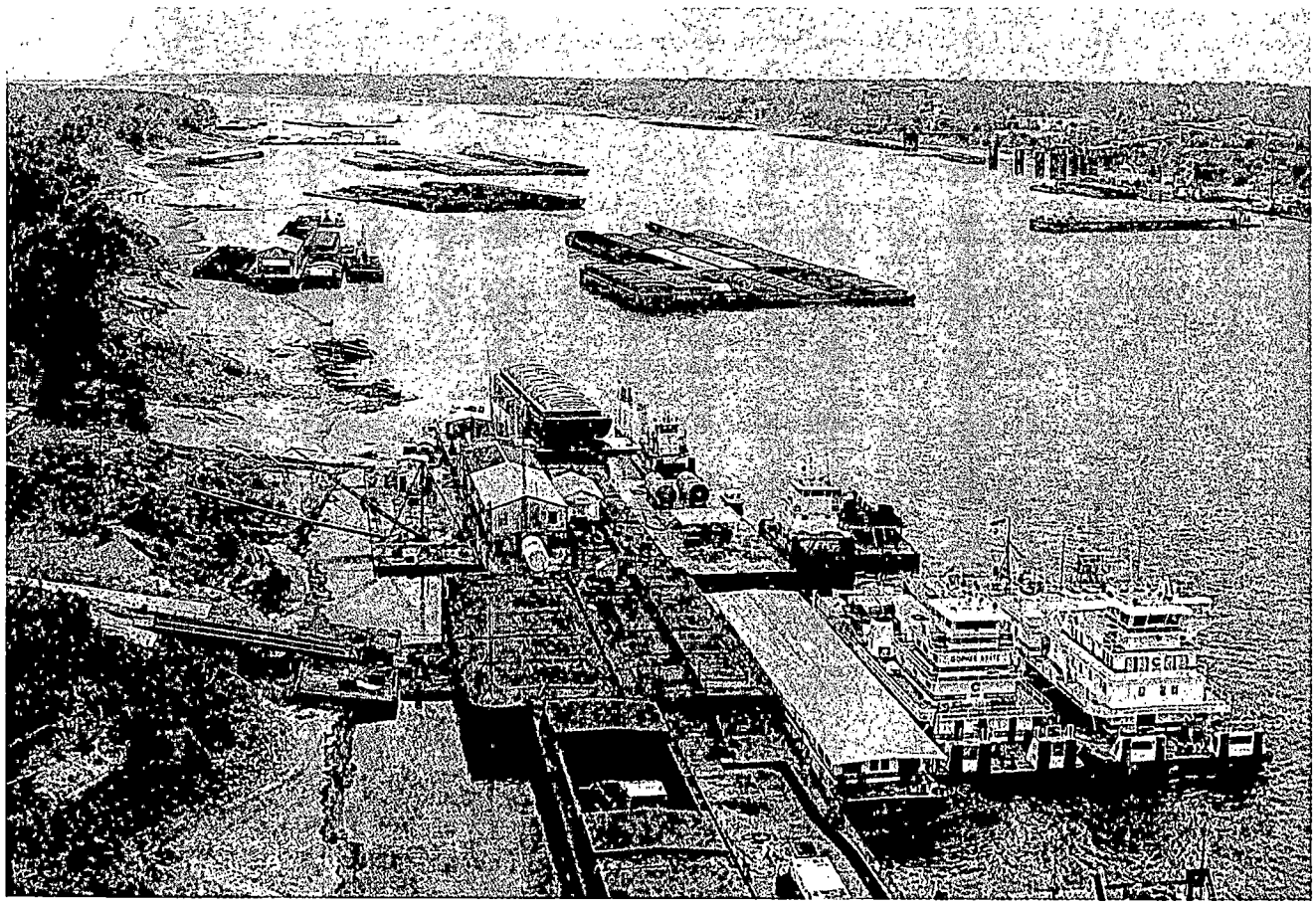
At the end of the 19th century the Swedish scientist Svante A. Arrhenius calculated how changes in carbon dioxide content would affect the temperature at the earth's surface. He estimated that a doubling of carbon dioxide would produce a global warming of about seven to 11 degrees Fahrenheit (four to six degrees Celsius), not too far off modern calculations. Yet it was only with the inception of the International Geophysical Year, a worldwide experiment in 1957 to monitor the global environment, that scientific data validating the increase of carbon dioxide in the atmosphere became available.

Roger Revelle, then director of the Scripps Institution of Oceanography, his colleague Hans E. Suess and C. David Keeling, his student, undertook such measurements. Revelle had long contended that humans were carrying out an unintended geophysical experiment on the atmosphere by burning fossil fuels. Determined to monitor the carbon dioxide content of the atmosphere, he persuaded Keeling to develop the instrumentation.

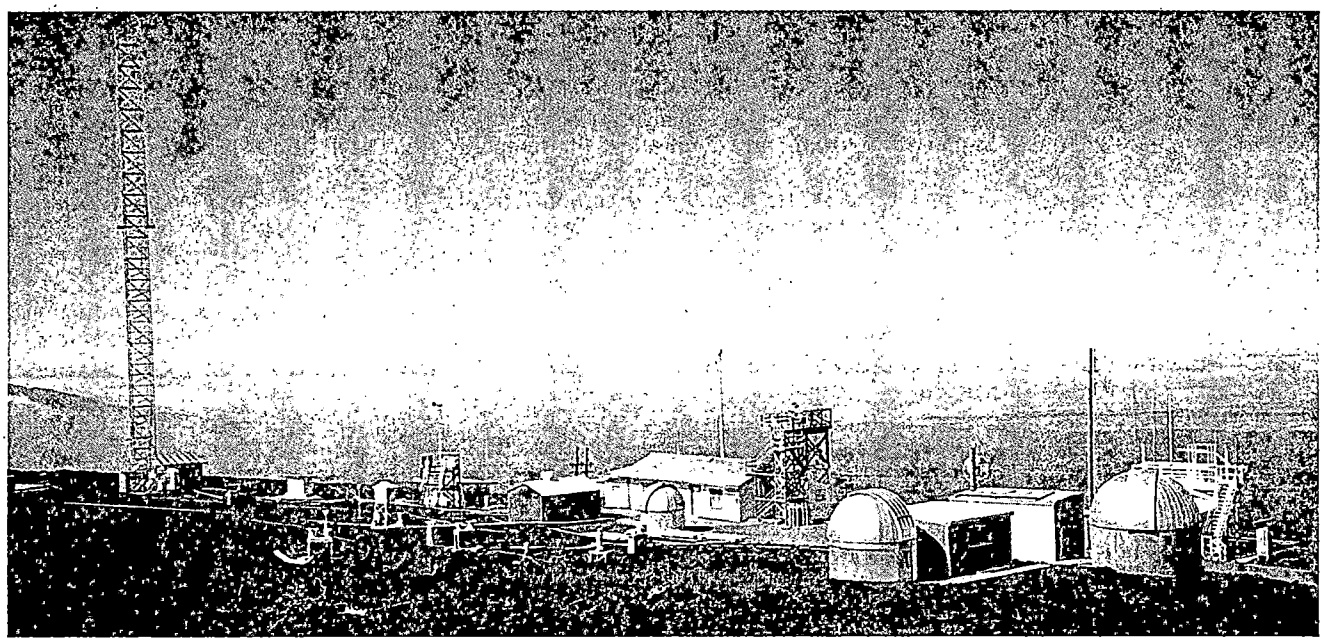
The measuring devices were placed in the Mauna Loa climate observatory in Hawaii at an altitude of about 11,000 feet. Beginning in 1957, the data they collected revealed a systematic increase in atmospheric carbon dioxide. Keeling's observations were verified at the South Pole and at other locations around the world. To date, the change from 290 parts per million in 1880 to 352 parts per million in 1989 represents more than a 20 percent increase over the course of the past century.

Just before the International Geophysical Year began, on the other side of the continent from Scripps, another development key to unraveling the climatic consequences of increasing carbon dioxide emissions was taking place. Under the leadership of the world-famous mathematician John von Neumann at the Institute for Advanced Study in Princeton, N.J., the first attempts were made to represent the atmosphere mathematically on digital computers.

Von Neumann's team of brilliant young scientists was headed by Jule G. Charney. Later known as the father of



BARGES STRANDED by all-time low water levels on the Mississippi River were one effect of the record-breaking drought of 1988. That long, hot summer thrust the greenhouse effect into the public eye and set off the present policy debate.



MAUNA LOA CLIMATE OBSERVATORY in Hawaii is located at about 11,000 feet. Data collected here, beginning in 1957 and continuing through the present, were the first to document a steady increase in atmospheric carbon dioxide levels.

numerical weather prediction and arguably the most important American figure in the transformation of weather prediction from art to science, Charney demonstrated the feasibility of using computers to perform the task. Von Neumann and Charney calculated the first 24-hour weather forecast in 1950 on a primitive digital computer, the ENIAC, maintained by the U.S. Army Signal Corps in New Jersey.

Looking beyond these efforts, von Neumann called climate forecasting the "infinite prediction." One of the young scientists in the Princeton group, Norman Phillips, made the first attempt at modeling the global atmosphere in 1956. It was coincidence that later, in 1963, an unusual laboratory of the National Oceanic and Atmospheric Administration (NOAA) was established on the campus of Princeton University under the leadership of Joseph Smagorinsky, a strong-willed and hard-driving young scientist who had been one of von Neumann's group. The laboratory was totally devoted to the mathematical modeling of the atmosphere using the largest and fastest digital computers available.

Called the Geophysical Fluid Dynamics Laboratory, the center harbored researchers from many nations interested in this new approach to the study of the atmosphere. Among them was a young Japanese scientist, Syukuro Manabe. Modest and retiring but completely dedicated to the work, he developed the first climate model in collaboration with his colleague Richard T. Wetherald in the 1960's. In 1975 they calculated that a doubling of the carbon dioxide content of the atmosphere would produce a global climate warming of about five degrees F (three degrees C), averaged over the surface of the earth. This calculation has been verified in many different laboratories and has not changed substantially.

Keeling's observations, together with the calculation of Manabe and Wetherald, triggered the wave of climate-change research that has marked the past two decades. Studies have since been undertaken in many parts of the world, including Europe and the Soviet Union. In the U.S. the National Research Council conducted studies in 1966, 1977, 1979, 1983 and 1987. These inquiries were chaired by such leading scientists as Gordon J. F. MacDonald, Revelle, Thomas F. Malone, Charney, William A. Nierenberg and economist William D. Nordhaus.

Yet because there were no immediate consequences for human health and no evident manifestation of climate change, the work was slow to arouse political concern. The most politically influential study was the one prepared in 1979 at the request of Frank Press, now president of the NAS, who was then White House science adviser to President Jimmy Carter. It was also in 1979 that the World Meteorological Organization in Geneva, recognizing the potential global significance of the issue, convened the first World Climate Conference.

Gradually, scientific awareness that humanity might actually be causing a planetary disruption began to register in the political world. Although there was much debate over the validity of projections from computer models, the observations of greenhouse-gas increases, however, were precise, well measured and verified in many parts of the world. These were corroborated by additional data that documented increases in other greenhouse gases such as methane, or natural gas, and CFC's.

Meanwhile mathematical-modeling groups in this country had been established not only by the NOAA but also by the National Aeronautics and Space Administration, the Department of Energy and the National Science Foundation. The leaders of these laboratories became the "gurus" of climate warming. Incisive and original in their work, Stephen H. Schneider of the NSF's National Center for Atmospheric Research in Boulder, Colo., and James E. Hansen, the leader of NASA's Goddard Institute for Space Studies, were soon to become frequent witnesses at innumerable congressional committee hearings on the subject.

Although the mathematical models of all the groups yielded similar results, the details of the geographic distribution of climate changes differed from one model to the other. All projected that an increase in carbon dioxide would bring about a gradual warming, but the timing of this warming would depend on the rate of global energy use. They all agreed that

if reasonable assumptions were made about future global energy consumption, it would be around the middle of the next century that the carbon dioxide content of the atmosphere might double.

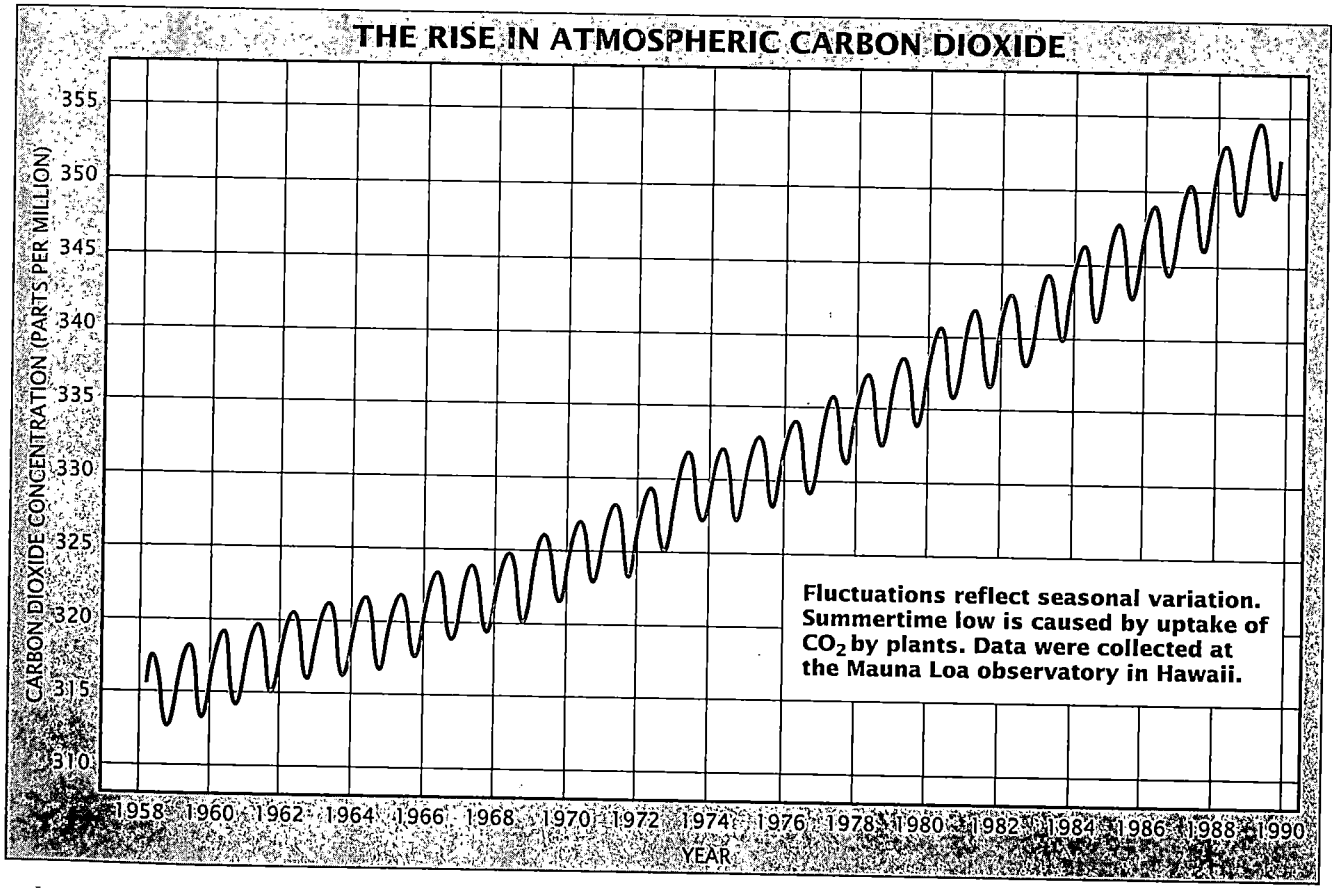
Just how much this doubling of carbon dioxide would increase temperatures, however, varied greatly from model to model. Some predicted as little as a two-degree F (one-degree C) increase, whereas others predicted increases of as much as nine degrees F (five degrees C). The differences in predictions became central elements in the debate about whether the models were sufficiently reliable to warrant policy actions. Further, it made a great difference whether the actual increase was at one or the other end of this range. At the low end, the normal resilience of society would probably be sufficient to accommodate the changed climate. Changes at the high end portended severe disruptions.

These projected temperature changes may appear innocuous because variations of this magnitude are experienced in the normal course of daily and seasonal weather. Their full implications can be appreciated by noting that it took only a two-degree F average decrease in temperatures in Europe to cause the run of several frigid centuries (from the 1400's to the 1800's) known as the Little Ice Age. Nine degrees F is believed to be the difference in temperature that separates the end of the last great ice age 12,000 years ago from the present. Further, the projections indicate that the Northern Hemisphere would experience in just a half century an unprecedented temperature change, 10 to 50 times faster than the change since the last ice age.

Those who are not familiar with mathematical models or the way computers are used to make these projections can be forgiven for being confused—or even annoyed—by the great disparities in the results. Among investigators it is understood that mathematical models are only approximations that attempt to simulate the processes that govern atmospheric behavior. The atmosphere is so complex that it is impossible to represent it in very great detail in these mathematical models. It is possible to represent only certain features and to make assumptions about how the oceans and the atmosphere interact, how the rate at which the oceans take up carbon dioxide varies and how clouds affect the exchange of energy between the earth and the atmosphere. Even the largest computers cannot represent the atmosphere, oceans and land surface in fine detail. Indeed, scientists approximate the conditions in the atmosphere by thinking of it as a set of observations spaced about 500 kilometers apart.

The political calls for action are being played out against the backdrop of that uncertainty. On one side, the view is that if there is a chance that model predictions could be correct, the consequences could be so dire that immediate action to arrest climate change would be imperative. The alternative view, equally cogent, is that commitment to action with vast economic and social consequences is unwarranted in light of both the scientific uncertainty and the absence of knowledge of the economic costs. John H. Sununu, White House chief of staff, in remarks he made at the annual meeting of the National Academy of Engineering in the fall of 1989 gave voice to this position:

Although I agree that [global warming] *is a critical issue, the fact is that the models with which analysis is being done and with which policy is being moved, as good as they may be, still are based on element sizes measured in hundreds of kilometers in length and width, and tens of kilometers in thickness. I suspect that no one who has ever been involved in engineering simulation would feel comfortable making major*



decisions in which the elements were orders of magnitude greater than the details on which they were looking for information. And yet the fact is that we are moving toward binding international policy based on conclusions being drawn by policymakers who have no sense at all of the difference between the levels of confidence they should have and levels of confidence they want to have. A system is not valid just because it gives you the answers you want. And yet so much policy is being made in reaction to that principle.

The solution to the dilemma should be simple: Since the carbon dioxide content of the atmosphere has increased by more than 20 percent over the past century, we ought to be able to detect the climate warming in the global temperature record during the same period. Researchers have sought to do this, but it is a much more difficult task than it first appears. The problem is that climate is always in a state of natural fluctuation. Separating out the changes that are caused by increasing carbon dioxide from the natural changes is tricky scientific business. Moreover, the climatic temperature record is based on scattered and irregular observations not taken specifically for the purposes of determining climatic conditions.

Even so, careful analysis of these temperature records by scientists in the U.S. and in the U.K. sought to detect whether a climate warming has occurred and whether such warming is consistent with the prediction of the models. The prevailing view is that the climatic record over the past century for the entire globe reveals a net increase in temperature ranging from .5 to 1.0 degree F (from .3 to .8 degree C). But set against this conclusion is the disturbing result that similar increases in temperature cannot be detected over the past century in the U.S., where observations are numerous and accurate.

Even if the temperature rise is real, a puzzle remains that workers have been unable to unravel: Is the rise in global temperatures a natural fluctuation or a result of the increase in greenhouse gases? All that can be said is that the observed increase is consistent with the lower end of the temperature increases predicted by the computer models. Consequently, the temperature records, as well as the predictions of mathematical models, provide substance both to those who believe the evidence warrants action now and to those who believe the evidence is still too weak.

The rush to policy action was, I believe, catalyzed by the disastrous drought of the summer of 1988. During this drought, one of the worst on record, the water in the Mississippi River fell so low that navigation was impossible over long stretches, urban water supplies were threatened and crops throughout the grain belt were devastated. Both officials and the public wondered whether this was the greenhouse effect manifest. Indeed, records show that in the U.S. five of the years of the 1980's were among the hottest on record, and the average temperature for the decade as a whole was the warmest since instrumental records have been kept.

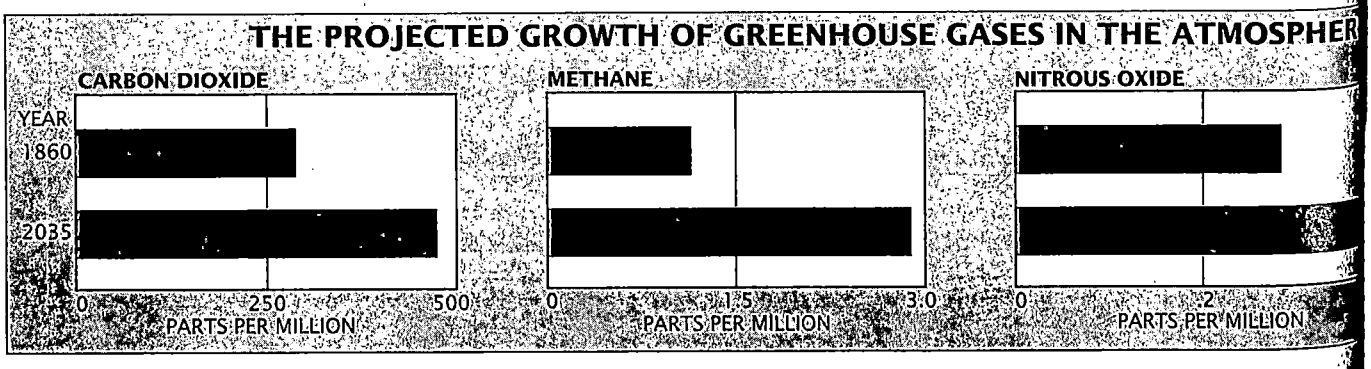
Prompted by heat and drought, congressional hearings addressed the question of whether the greenhouse effect had arrived. These hearings were unremarkable except for a statement by Hansen. When he stated that he was 99 percent certain that the greenhouse warming had begun, as evidenced by the sequence of warm years in the 1980's, the public took notice. His opinion prompted members of Congress to consider whether the prudent course was to move rapidly to legislation aimed at protecting the habitability of the planet from catastrophic consequences.

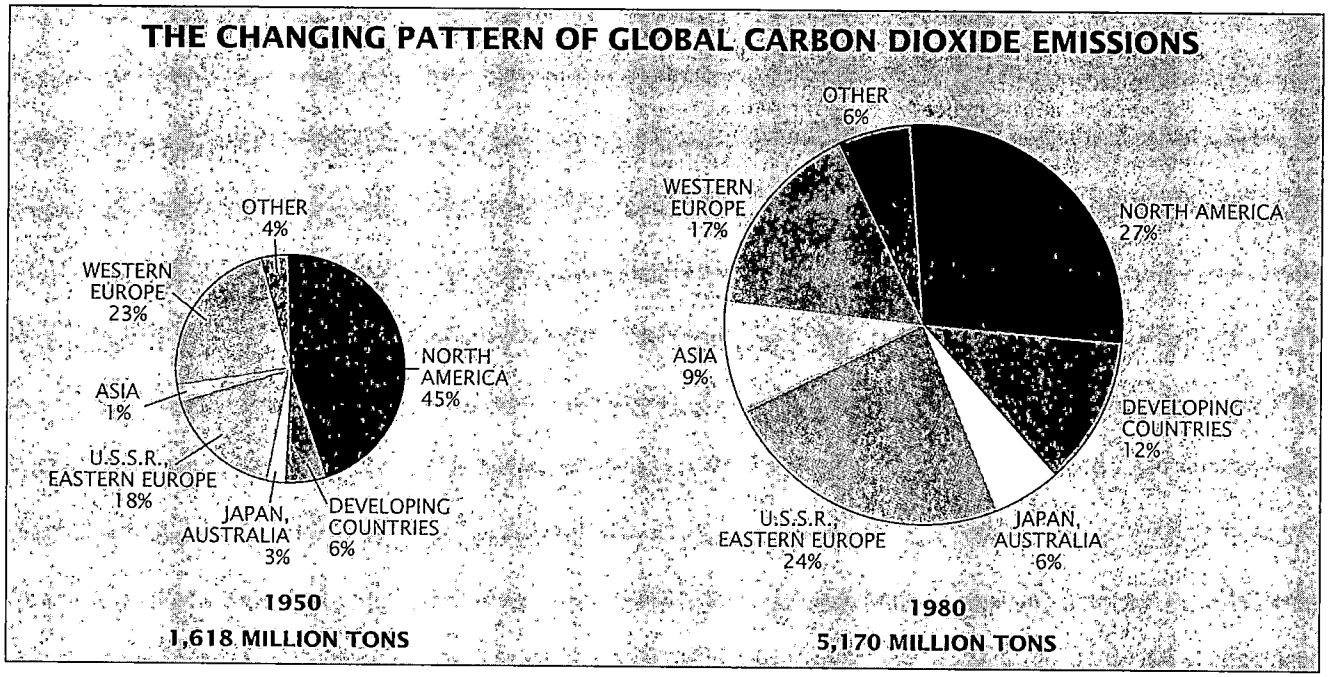
Hearings followed hearings. Both the atmospheric researchers and the more general environmental community began to choose sides on whether immediate policy action was justified. The reaction from environmentalists was quick and vociferous. Several environmental and scientific groups began to advocate international agreements restricting the emissions of greenhouse gases.

At this point, some influential atmospheric researchers, who believed that policy actions were beginning to outrun the scientific evidence, weighed in with their views. Richard S. Lindzen of the Massachusetts Institute of Technology and Jerome Namias of Scripps, the nation's most distinguished long-range weather-forecasting expert, wrote a letter to President Bush urging that no action be taken. Three other members of the NAS, including its former president Frederick Seitz, joined in a report, published under the auspices of the Marshall Institute, calling into question the scientific basis for policy actions. They recommended a major research program in mathematical modeling. They pointed out that there might be alternative explanations for the climate warming that had taken place. Thus, the great climate debate had been joined.

Meteorologists did not look with favor on the prospect of yet another public debate involving their field: they had been proved wrong many times before. As long ago as 1924, Sir Gilbert Walker, then head of the British government's Indian weather service, discerned unusually close connections between rainfall, temperature and pressures in the Pacific Ocean and the Indian subcontinent. Claims were made that the problem of forecasting the Indian monsoon was solved. Were it true, it would have been a great boon to Indian agriculture. But it was soon recognized that the correlations had little predictive power.

Later, in the 1940's and 1950's, widespread claims were made, based on the work of the late Irving Langmuir, Nobel laureate from the General Electric Company, and Vincent J. Schaefer of the State University of New York at Albany, that seeding clouds with dry ice or crystals of silver iodide could bring about an increase in rainfall. Several decades of research into the possi-



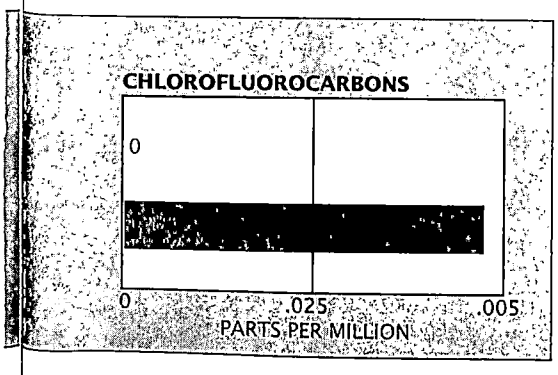


bilities of increasing rainfall, changing the intensity of hurricanes and modifying hailstorms by cloud-seeding techniques proved abortive.

Then, in the early 1980's, it was postulated that dust thrown into the atmosphere by a nuclear exchange between the Soviet Union and the U.S. would result in a "nuclear winter." This idea was deflated by Schneider and his colleague Stanley L. Thompson, who showed with the same models used in the prediction of climate that the "initial nuclear winter hypothesis can now be relegated to a vanishingly low level of probability."

Given this "cry wolf" history, it is not surprising that many meteorologists harbor deep reservations about taking costly actions on the basis of the predictions of a climate warming. But the push for policy has other constituents. Climate warming also unites those who are concerned about biodiversity and species extinction, economic development, human population growth, urban air pollution, acid precipitation and ozone depletion.

Political leaders stimulated by public concerns about environmental deterioration see these issues as important platforms and as springboards to public office. Those interested in increasing the competitiveness of American industry see greater energy efficiency as an important step toward that goal. It also serves the interest of those concerned about U.S. dependence on foreign energy sources. The issue of nuclear power is also underscored. Because fossil fuels are the main source of atmospheric carbon dioxide, strategies for stabilizing climate must envision non-fossil-fuel sources. Here at last is justification that proponents of nuclear power can forcefully advance to support expansion of nuclear power facilities throughout the world.



The issue of global climate warming also offers an opportunity for advancing the "new economic order" long advocated by Third World nations. International action will require technological and economic assistance to such nations if they are to participate in a global effort to reduce atmospheric pollution or arrest deforestation. In fact, the world faces the prospect that the greatest increases in emissions of carbon dioxide will occur in developing countries as their need for economic growth is followed by increased demand for energy.

In like manner, those interested in arresting population growth, especially in the Third World, point out that the climate-warming problem is probably not solvable as long as the number of human beings continues to rise. After all, it is people who consume natural resources and energy and who farm the land. Without population control, prospects for stabilizing the climate and arresting the deterioration of the habitability of the planet are abysmal.

Are the consequences of climate warming to be feared? People experience extremes of temperature in the natural course of events. The fact is that we do not know enough to predict the severity of the consequences. Because the warming would not be uniform over the surface of the earth, it would probably produce both winners and losers among regions and nations. Some parts of the earth would become warmer, some wetter and some drier. It is not possible on the basis of the evidence at hand to predict who would benefit and who would lose in such a global redistribution of so-called climatic resources.

Some aspects of global climate warming would be greatly beneficial in the view of agricultural researchers. Increased carbon dioxide will foster more active photosynthesis and enhance crop growth, to say nothing about the lowered plant requirements for water in a CO_2-enhanced atmosphere. In the words of Jerry D. Mahlman, director of the Geophysical Fluid Dynamics Laboratory, "The things we can say with confidence, the policymakers are not interested in. And the things [they] are interested in, we don't know with confidence."

Models do, however, agree that the polar regions of the world would undergo greater increases in temperature than would the tropics. Some of the projections of temperature increases in polar areas are startling in their magnitude, predicting as much as 18 degrees

F (10 degrees C) on the average in the Northern Hemisphere and only slight increases in tropical regions.

What are the general consequences of such a change in the temperature difference between equatorial and polar regions? We experience similar differences every year as the seasons change. In summer when arctic temperatures are warm, we do not suffer the great storms of winter; precipitation belts move farther north. Areas such as the southwestern part of the U.S. experience very dry conditions.

If arctic regions were to undergo significantly greater warming than equatorial regions and if precipitation belts were to move farther north, countries in the north temperate and polar zones would probably stand to benefit greatly. Their growing season would lengthen, and their precipitation would increase. With suitable soils, agriculture might thrive. These are speculations, however.

Such speculations are formulated in "scenarios" asking the question, What if? Unfortunately, an infinite number of such "what if" questions may be asked. What if the flow of rivers in the American Southwest, already fully utilized, were to be reduced by 20 percent? What if temperatures were to increase in the corn belt and precipitation were to move farther north? What, then, would be the consequences in the U.S. for agriculture, for resource availability, for energy generation, for national parks and conservation of nature?

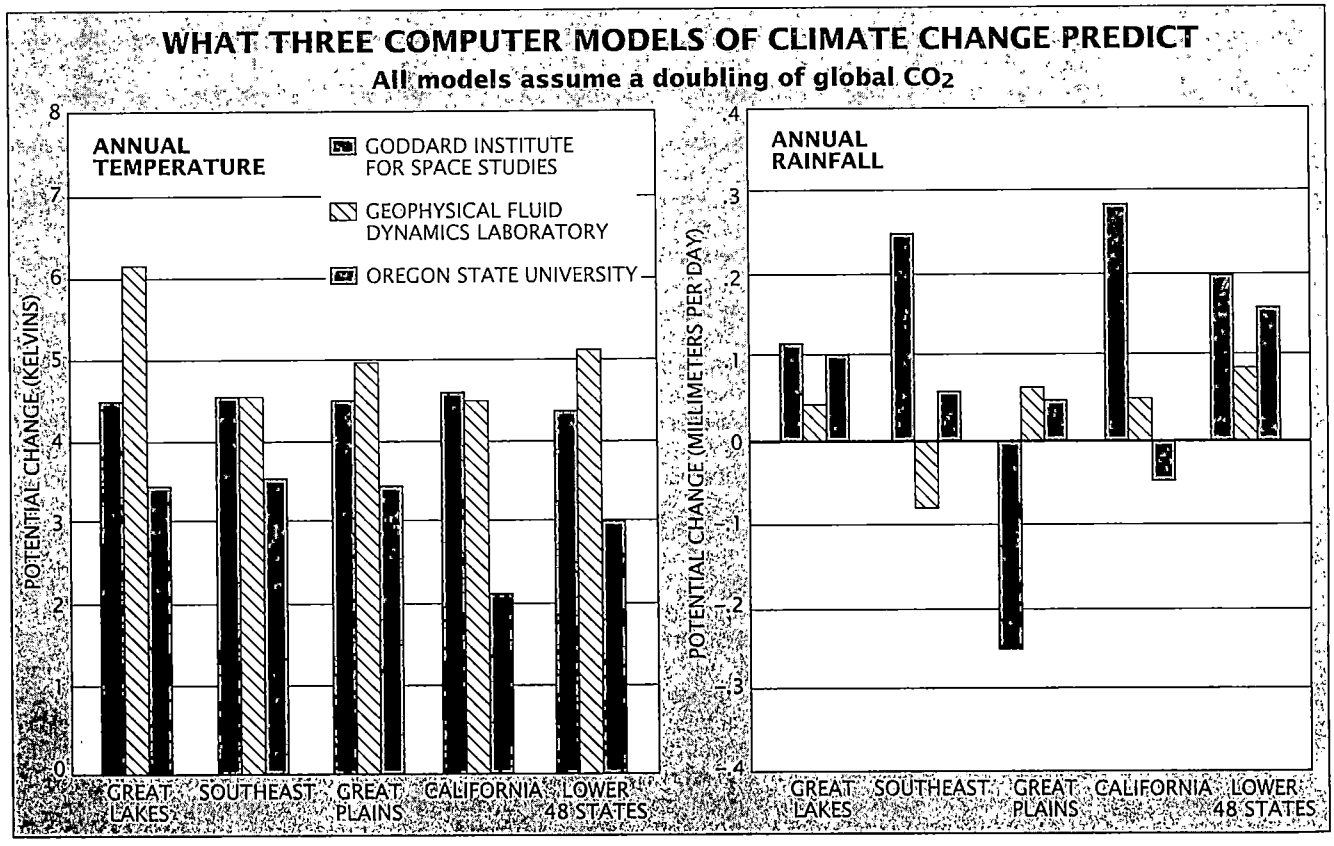
The consequences of changed climates can be seen in historical records going back thousands of years, and we have seen them in recent climatic events. We know, for example, that the Danes were able to settle Greenland and the Vikings to sail the North Atlantic to North America during a period of warm climate around the year 1000. Then a significant change in climate caused the collapse of the Danish settlements, prevented further exploration of the North American continent and ushered in the Little Ice Age. In just the past few years we have witnessed the effects of drought in the Sahel region of Africa and northeast Brazil, as well as in parts of North America.

Such scenarios can suggest apocalyptic possibilities. A recent film in the *Infinite Voyage* television series showed the U.S. Capitol under water as the result of one possible climate-warming scenario. Some foresee vast migrations of people as areas of the world become uninhabitable. Others see threats to national sovereignty and national security. President Gorbachev has stated that ecological security, not military security, will be the principal concern of all nations in the next century as environmental conditions cause disruptions worldwide.

But scenarios should be qualified with the caveat that although the events portrayed might in some cases be plausible, they are not real predictions. What, then, is a wise course in the face of great uncertainty? Clearly, it would be one that recognized uncertainty but would not permit that uncertainty to forestall action. Steps for which other economic and environmental reasons make sense would be taken first, whether or not a climate warming is taking place [see "The Changing Climate," by Stephen H. Schneider; SCIENTIFIC AMERICAN, September, 1989].

Then, as scientific knowledge reduced uncertainties, more costly measures could be taken if warranted, hence closely tying policy actions to the state of knowledge. Scientists and others have called this a "no regrets" policy. In gambling it would be known as "spreading your bets."

A recent report of the Council of Economic Advisers lends weight to this approach. It states that the cost of controlling carbon dioxide emissions and of taking other actions to address climate change would run into hundreds of billions of dollars. Because such reallocations of resources raise the specter of grave economic consequences, we need to be reasonably sure such ac-



tions are worth the cost. Any rational no-regrets policy would foster as one of its prime objectives adequate investment by governments in global monitoring and mathematical modeling to reduce the scientific uncertainties.

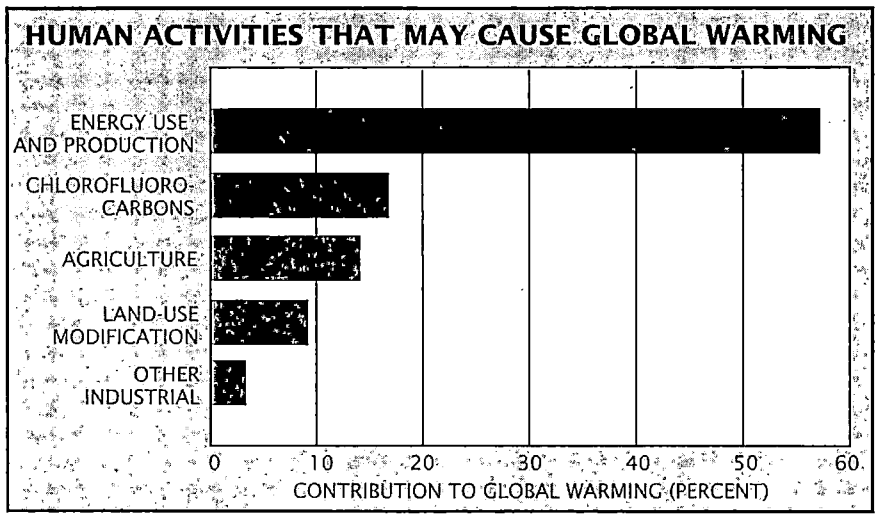
Where might we start? Energy conservation and efficiency along with the phaseout of CFC production would be the first priority for national and international action. Achieving greater energy efficiency justifies itself handily in economic terms. Increased energy efficiency would also ameliorate urban air pollution and acid precipitation. Shifts in the fossil-fuel mix from coal and oil to natural gas could significantly reduce carbon dioxide emissions per thermal unit. Technology is also available for more efficient power generation and for increased gasoline mileage.

Wisdom would also dictate major investments in nonfossil-energy sources. The circumstances favor significant new investments in passively safe, publicly acceptable nuclear power. Further development of forms of solar energy—photovoltaics or biomass, for example—makes good sense. Reforestation and forest preservation constitute a benign policy that yields many ecological and climatic benefits. Research aimed at producing stress- and disease-resistant crops would also be wise.

The public, however, must not be misled. These no-regrets initial policy steps will not solve the climate-warming problem. Their effectiveness will only modestly retard climate warming, and the future may require more drastic actions. No matter what policy actions we take, fully arresting the climate warming just does not seem to be in the cards.

The difficulties of reaching an international agreement on procedures for mitigating climate warming will be difficult and lengthy. The negotiations for the Law of the Sea Treaty provide a good lesson. They consumed 15 years and produced a treaty that the U.S. has yet to sign because of demands by developing nations for significant technology transfer and economic assistance. These issues will be even more complicated and more pervasive in any "Law of the Atmosphere Treaty."

It is likely that humanity will have to adapt to some climate changes. Modes of adaptation by society have not been well studied. Individuals, corporations and communities can adapt to climatic vicissitudes in myriad ways. Farmers can change crops, water use can be regulated and management practices can be altered.



Other modes of adaptation would be needed if climate changes were severe. Sea-level rise, which is one of the predicted concomitants of a climate warming, might inundate low-lying coastal areas and cause salt water to intrude into freshwater bodies. Were this to occur, society would have to decide whether to invest in protective structures along coasts or adapt by changing land-use patterns. The North Sea dikes in the Netherlands are an outstanding example of adaptation to relative rise in sea level.

Some adaptations would take considerable time to implement. If the price of energy were to escalate, energy-efficient habitations would be necessary. Present cities with their great suburban sprawl are not energy efficient, and so we might return to more compact cities. If we chose to maintain agriculture in dry areas, society would need to decide whether to invest in the necessary irrigation systems. In fact, the economic growth of the entire western part of the U.S. has been based on major investments in water storage and transport for irrigation and industrial use.

Fortunately, time may for once be on our side. Governments generally act only when threats become real. They act in the face of military threats or when areas are endangered and destroyed by natural disasters. If the climate changes, the expectation is that it will do so gradually. We should be able to see the initial evidence of coastal inundation in an increasing frequency of high tides and in the undercutting of seacoasts. Climate warming itself should be evident in a rising frequency of heat waves or in other weather anomalies. The effects of a global climate warming are likely to take 30 to 50 years to become serious, and that is a long enough span in which actions to adapt to these changes should be possible.

What of the debate in the atmospheric, environmental and political communities? Our global environment is under attack on many fronts. Climate warming is but one, perhaps the most complex, of these issues. If the changes occurring in our atmosphere are likely to cause consequences, we must understand the problems and promote sensible policies to remedy them. What would be unwise is to lapse into apocalyptic thinking or ostrichlike denial. We like to believe ourselves far more sophisticated, more enlightened, than preceding generations. Until we can calmly and objectively approach our environmental challenges without promoting public hysteria and exciting shortsighted, self-interested reaction, we cannot claim that we are.

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Convergence Rate and Stability of Ocean-Atmosphere Coupling Schemes with a Zero-Dimensional Climate Model

ROBERT E. DICKINSON