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Global Climate Change [1][3]

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Page 1 of 1

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File Location: Global Climate Change [1][3]

Pinksheet Number: ES795
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WHITE HOUSE CORRESPONDENCE TRACKING WORKSHEET

☐ O - OUTGOING☐ H - INTERNAL☐ I - INCOMINGDate Correspondence
Received (YY/MM/DD) 1 1Name of Correspondent: D. Allan Bromley☐ MI Mail Report

User Codes: (A) _____ (B) _____ (C) _____

Subject: Global Change Framework Convention
Negotiations

ROUTE TO:

ACTION

DISPOSITION

Office/Agency	(Staff Name)	Action Code	Tracking Date YY/MM/DD	Type of Response	Code	Completion Date YY/MM/DD
	<u>Cuofc</u>	ORIGINATOR	<u>9/10/10</u>			<u>1 1</u>
	<u>Cuat 17</u>	Referral Note: <u>A</u>	<u>9/10/10</u>		<u>S</u>	<u>9/10/11</u>
	<u>Cuat 02</u>	Referral Note: <u>E</u>	<u>1 1</u>			<u>1 1</u>
	<u>Cugay</u>	Referral Note: <u>E</u>	<u>1 1</u>			<u>1 1</u>
		Referral Note: <u>-</u>	<u>1 1</u>			<u>1 1</u>
		Referral Note: <u>-</u>	<u>1 1</u>			<u>1 1</u>

ACTION CODES:

A - Appropriate Action
C - Comment/Recommendation
D - Draft Response
F - Furnish Fact Sheet
to be used as Enclosure

I - Info Copy Only/No Action Necessary
R - Direct Reply w/Copy
S - For Signature
X - Interim Reply

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Type of Response = Initials of Signer
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THE WHITE HOUSE
WASHINGTON

January 10, 1991

MEMORANDUM FOR THE GLOBAL CHANGE STRATEGY TASK FORCE

FROM: D. ALLAN BROMLEY
SUBJECT: Global Change Strategy Task Force Meeting

The Global Change Strategy Task Force will meet Friday, January 11, 1991, at 3 p.m. in Room 476 of the Old Executive Office Building.

As we discussed at our meeting last week, we will review a draft paper on key issues related to the preparations for the first negotiating session of the Framework Convention for possible submission to the Domestic Policy Council. Enclosed is a copy of that paper for your comment, but note that the document should be treated as "Close Hold". Please be prepared to discuss the issues presented in the paper at the meeting. Additional comments should be forwarded to Nancy Maynard at 456-6202 by COB Friday January 11, 1991.

Thank you

Enclosures

COUNSEL'S OFFICE
RECEIVED
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January 10, 1991

MEMORANDUM

FROM: D. ALLAN BROMLEY

SUBJECT: Global Change Framework Convention Negotiations

Issue: Negotiations on a global response to possible climate change will take place over the next 18 months under UN General Assembly auspices, with the aim of agreeing on the text of a framework convention in time for signing at the June 1992 UN Conference on Environment and Development (UNCED) to take place in Rio de Janeiro, Brazil. The United States will host the first session of the negotiations in Washington from February 4 to 14. The first session is expected to focus on organizational matters and the preparation of an initial negotiating text, without any attempt to resolve differences until subsequent sessions. The text will be based largely on the work of the Intergovernmental Panel on Climate Change (IPCC), which completed its first interim report last Fall.

BACKGROUND

Science: Scientific research has attempted to determine whether global warming is a potential threat and, if so, what would be the appropriate policy responses. Although atmospheric monitoring has shown an increase in concentrations of greenhouse gases, the mechanism of this increase, its natural and human components, and its potential effect on the earth's temperature regulation process and on climate change are unclear. What is known is that some human activities (such as the burning of fossil fuels, cattle raising, rice paddies, and garbage dumps) contribute to atmospheric concentrations of greenhouse gases (e.g., carbon dioxide - (CO₂), methane, nitrous oxide, and chlorofluorocarbons). An increase in greenhouse gases increases the atmosphere's retention of heat. A complex natural system of temperature regulation can adjust to changes in temperature and greenhouse gas concentrations. It bears emphasis that the greenhouse gases entering and exiting the atmosphere through natural processes are more than twenty times larger than those resulting from human activities. This system involves complex cycles of emissions from "sources" of gases and sequester by "sinks". These cycles also include the absorption and radiation of energy.

Much effort has been undertaken to create computer models of this complex system in order to predict the effects on climate change of different levels of greenhouse gas concentrations. However, due to its complexity, the natural system of temperature

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regulation has never been accurately reflected in models, leading to uncertainties in the science and limited ability to predict climate change. Thus, there are great differences of opinion regarding the magnitude, spatial distribution, and timing of any climate changes caused by increased concentrations of greenhouse gases and the effect of natural mitigating factors. Moreover, the models are reasonably successful in representing global average phenomena, and incapable presently of giving reliable predictions on a regional basis. It is these smaller scale predictions that are of the greatest interest in developing economically viable measures to respond to potential global climate change.

International Action: The United States has participated in and endorsed the activities of the Intergovernmental Panel on Climate Change (IPCC). The IPCC was set up in 1987 by the World Meteorological Organization and the United Nations Environment Programme to assess the scientific information pertaining to the climate change issue, to assess impacts and to assess the factual basis for possible strategies to assist in controlling and responding to climate change. The IPCC adopted an interim report at the Second World Climate Conference in November 1990. The report addresses four major areas of climate change: 1) research, 2) the impacts of potential change, 3) response strategies, and 4) legal measures to implement response strategies, including possible elements of a framework convention on climate change. The report gives the current international perspective on global climate change and will form the basis for these international negotiations on a framework convention on climate change.

Congressional Action: There has been growing interest in global climate change issues among members and committees of the Congress. Over 50 bills, concurrent resolutions, and amendments were introduced in the 101st Congress dealing with various aspects of this issue. In addition, Congress has increased its attention to activities both of the Executive branch and the international community in global change research and international discussions. Congressional interest and activity will certainly increase in the 102nd Congress, with likely impacts on the framework convention negotiations.

Economics: Policy in this area must weigh the economic costs and human consequences of proposed response measures against the benefits associated with any resulting change in the timing and magnitude of any possible warming. Current analyses of the costs of a commitment to permanently hold carbon dioxide emissions at 80 or 100 percent of present levels show widely varying assessments of impacts on output and economic growth. Most studies using aggregate methods show an impact in the range of .05 percent to 1 percent of GNP (about \$35 to \$70 billion) at the turn of the century. Particular sectors, such as coal mining, would be particularly hard hit. Also, because the share of fossil fuels in the total primary energy supply varies widely across industrialized countries, there are likely to be significant trade and competitiveness effects.

Some "bottoms up" analyses show that the substitution of more energy-efficient technologies (better lightbulbs, more insulation) can contribute to emissions reduction on the near term without raising the lifecycle cost of energy-using activities. Such evaluations do not account for the differences in taste and usage across consumers or the need to weigh energy-efficiency investments against alternative uses of capital. Obtainable energy savings and emissions reductions are almost certainly lower than estimates of technological potential.

Maintenance of any constant emissions level implies an ever increasing percentage reduction from an emissions baseline that is expected to grow as the economy expands. Since the marginal cost of emissions reduction increases after the cheapest opportunities are exploited, both aggregate and "bottoms up" modelling suggests that the costs of a constant emissions target are likely to rise over time. Finally, in considering the possible benefits of emissions reductions, it must be recognized that climate processes depend on world emissions, which are dominated by expected emissions increases outside of the industrialized countries.

Energy Issues: In spite of the relatively small contribution made by human activities, concerns about climate change and the build up of greenhouse gas concentrations have led to discussions of ways to reduce manmade emissions. Fossil fuel use is one source of these emissions. U.S. fossil fuel use produced almost 6 billion tons of CO₂, one major greenhouse gas, in 1988. This represents about 25% of total human induced emissions world-wide.

Since 1973 various strategies have been used to reduce our dependency on foreign oil imports. Additional steps to address energy issues could have an impact on the level of greenhouse gas emissions if they involve incentives to reduce fossil fuel use or increase the use of alternative energy sources, such as energy efficiency, conservation, or substitution.

CLIMATE CONVENTION NEGOTIATIONS

Process: The climate change negotiations will be carried out through a single process and forum provided by the Intergovernmental Negotiating Committee (INC). Following the first session here in Washington, most of the negotiating sessions will be held at UN facilities in Geneva, with one or possibly more sessions in Nairobi. Sessions will be one to two weeks in length, at intervals of three to four months in 1991, that is, in May or June, in August or September and in November or December. One to two sessions will be scheduled as needed in 1992. Jean Ripert of France will likely chair the negotiations. At the first session the United States will press for all substantive decisions to be taken by consensus and will seek appropriate participation by NGOs (non-governmental organizations, including both environmental and industry groups).

DRAFT

U.S. Delegation: The U.S. delegation for the first session will be headed by Curtis "Buff" Bohlen, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs. The alternate head of delegation will be Robert A. Reinstein, Deputy Assistant Secretary of State for Environment, Health and Natural Resources. Reinstein will function as negotiator for this and subsequent sessions. The negotiating team is expected to include 12-15 representatives of the agencies with relevant environmental, scientific and economic expertise.

Scenario for First Session: Although a draft agenda has not yet been circulated by the UN Secretariat the following work-plan is anticipated for the nine-day session:

- o Organizational matters -- 1 day;
- o initial country statements (more than 100 countries are expected to attend) -- 2 days;
- o establishment of subgroups and preparation of the legal negotiating -- text 5 days;
- o and other matters (including establishment of relationship with IPCC and setting date and place of next session) -- 1 day.

Countries will propose text they wish to see included in the convention. All of the proposals will be bracketed in those instances where the text has not been agreed to by all participants. Although there will be some discussion of the reasons why specific text is being proposed, an attempt to resolve brackets will not be made during the first session. The U.S. delegation will propose the inclusion of language for elements we wish to see included in the convention. U.S. proposals will concern trade particularly on scientific research and cooperation. U.S. proposals will seek to address greenhouse gases in a comprehensive manner, that will include consideration of all sources and sinks. U.S. negotiators will make it clear that the U.S. considers such a comprehensive approach, with its potential for sharing any obligations across sources and sinks, gases, and countries to be of fundamental importance.

Elements for Possible Inclusion:

A number of non-controversial elements that may be included in the framework convention have been identified by the IPCC. We expect additional elements to be proposed as well, including controversial elements that more properly should belong in future protocols to the convention dealing with specific commitments following-on general commitments made in the convention itself. Both types of proposals are discussed briefly below:

Noncontroversial:

- Preamble: This generally consists of hortatory language and declarative findings and is often negotiated after the body of the agreement has been completed. It may include statements on issues where the countries cannot agree and accordingly may be used for compromises.
- General obligations: A framework convention would usually contain a set of general obligations that may or may not be followed by specific commitments. One possibly potentially controversial general obligation may be raised by the inclusion of a formulation of the "Precautionary Principle" (discussed below).
- Institutions: Such agreements generally establish a permanent secretariat to carry out administrative functions (presumably institutionalizing the ad-hoc secretariat that will support the negotiations) and a Conference of the Parties, which is simply the mechanism through which the countries become Parties to implement the agreement.
- Research, systematic observations and analysis: This is a section of the agreement on which we will want to concentrate.
- Information exchange and reporting: The U.S., consistent with our preference for a comprehensive approach, will want to emphasize comprehensive monitoring and reporting of data on all sources and sinks of all greenhouse gases in these sections.
- Settlement of disputes: This is not controversial as long as there are no specific obligations.
- Final clauses: These include miscellaneous legal provisions, and requirements for, entry into force, amendments, withdrawal, etc.

Controversial:

- Annexes and protocols: The major issue to be debated over the next 18 months is the question of targets and timetables for reductions of greenhouse gas emissions, particularly CO₂ emissions from the burning of fossil fuels. We are committed to addressing all greenhouse gases in a comprehensive manner, and that we will not be part of any agreement that does not include a comprehensive approach. Any specific obligations of this kind would be included in annexes or protocols to the convention. We have taken the position that such commitments are not appropriate at this time and should be negotiated subsequent to signing of the convention in 1992, and then only if analysis demonstrates that they are necessary. All other OECD countries, except Turkey, have made political statements arguing that such obligations should be undertaken now, either as part of the convention itself or in protocols negotiated simultaneously with the convention.

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-- General obligations: the Precautionary Principle: Many countries are on record as wanting to include in the framework convention an article on the so-called "Precautionary Principle." To date, there is no internationally agreed definition of the principle. Some have described it as merely expressing the general notion that it is desirable to prevent pollution. Others have taken a more extreme position, describing it as meaning that, before an activity may be undertaken, it must be affirmatively proven that the activity will not cause harm to the environment. If unable to avoid it, we should seek a climate-specific definition of the precautionary principle or "precautionary approach" based on the [no-regrets] policy, that is a policy that will take into account the degree of scientific certainty and economic considerations.

-- Financial assistance: Consistent with the Houston Economic Declaration, a general commitment to promote financial assistance for developing countries will be raised in the framework convention. Developing countries will undoubtedly propose that this include a commitment to provide "new and additional" funding, a commitment that we oppose. The United States, and other donor nations, believe that financial assistance should be to meet incremental costs incurred, based on the extent to which global benefits of a project are expected to exceed benefits to the recipient country. The United States also believes that the newly established Global Environmental Facility (GEF) in the World Bank is the appropriate mechanism through which any multilateral assistance should be processed.

-- Development and transfer of technology: The developing countries have often called for technology transfer on a "preferential and noncommercial basis." Although this language raises the problem of protection of intellectual property rights (IPR), there is in fact, a wide range of technologies where IPR issues do not arise and where there may indeed be significant opportunities for providing technical assistance to developing countries through existing bilateral cooperation programs. As a counter to unreasonable demands in this area, we will need to explore some of these options as the negotiations proceed. We will also stress that failure to address the technology transfer question on a commercial basis, with full account taken of market forces and the protection of IPR, will act as a disincentive to the development of needed technology. A proactive approach to assisting in the application of technology that is readily available and does not involve IPR issues will benefit the environment, increase market share, give an opportunity for a positive political action, and enhance the development of new technologies.

Strategy: In addition to our substantive positions, we need to develop a realistic strategy to carry us through the course of the negotiations. Our strategy will need primarily to address two arenas: (1) the negotiations themselves, and (2) Congress and the U.S. public. The United States is entering these negotiations from a relatively isolated position, seeing it is the only major developed country not committed to some target and timetable for greenhouse gas reductions.

Within the negotiations themselves, we can bolster our basic position on the targets and timetables by demonstrating the economic costs of such commitments and their administrative complexities, possible trade problems arising from the imposition of

large taxes on the carbon content of fossil fuels (the principal means of achieving major reductions), and other problems that are far from being solved. This will require solid economic and scientific analysis in order to back up our positions. But such analysis is already well underway and partially completed.

Many other countries have expressed some doubt about our sincerity about addressing the climate issue. In this regard, any signal we might give that we are willing to take actions, even though fully justified for other reasons (such as energy security, longer-term industrial competitiveness, other proven environmental concerns, etc.), which would result in some significant reduction in greenhouse gas emissions would have a major beneficial strategic impact. Such a signal from the United States would also help to ensure that the climate negotiations do not affect other international environmental issues. It is important to emphasize that both in terms of the U.S. investment in a deeper understanding of the phenomena involved in global change, and in specific policy actions, that we are already acting to reduce U.S. greenhouse gas emissions. These U.S. activities are unmatched by any other country. For various reasons, the U.S. has found itself in a reactive mode in national and international media coverage. It will be essential for us to focus on changing the situation so that our achievements are widely recognized and credited to the President's initiatives and programs.

We expect the negotiations to receive considerable press attention. Foreign governments and U.S. environmental groups will use the media to further their positions, particularly during the first negotiating session. We will have a list of Administration achievements for distribution during the first session to the press and other governments. Congress to continue will also play a vocal role throughout the negotiations.

WELCOMING REMARKS OF
THE HONORABLE MICHAEL R. DELAND
CHAIRMAN, PRESIDENT'S COUNCIL ON ENVIRONMENTAL QUALITY

TO THE FIRST SESSION OF
THE U.N. INTERGOVERNMENTAL NEGOTIATING COMMITTEE
ON CLIMATE CHANGE

CHANTILLY, VIRGINIA, USA
FEBRUARY 4, 1991

DIRECTOR GENERAL BLANCA, DR. TOLBA, DR. OBASI, OFFICIALS OF
THE UNITED NATIONS, DISTINGUISHED DELEGATES, REPRESENTATIVES OF
THE NONGOVERNMENTAL COMMUNITY, LADIES AND GENTLEMEN:

ON BEHALF OF PRESIDENT BUSH, IT IS AN HONOR FOR ME TO
WELCOME SUCH A DISTINGUISHED ASSEMBLY OF PUBLIC OFFICIALS FROM SO
MANY NATIONS. THE PRESIDENT AND ALL AMERICANS ARE DELIGHTED TO
PROVIDE A FORUM FOR THE UNITED NATIONS TO BEGIN NEGOTIATIONS ON A
LANDMARK INTERNATIONAL CONVENTION ON CLIMATE CHANGE.

PRESIDENT BUSH SENDS HIS PERSONAL GREETINGS TO EACH OF YOU,
AND REGRETS THAT HE CANNOT BE HERE IN PERSON THIS MORNING. HE
BELIEVES DEEPLY IN THE UNITED NATIONS, AND KNOWS FIRSTHAND WHAT
REMARKABLE THINGS CAN BE ACCOMPLISHED WHEN DIVERSE NATIONS WORK
TOGETHER TOWARD COMMON OBJECTIVES.

AS WE ENTER THESE NEGOTIATIONS, LET ME SHARE WITH YOU THE
UNITED STATES' OUTLOOK:

O **FIRST,** WE BELIEVE THAT A COMPREHENSIVE STRATEGY FOR ACTION MUST FLOW FROM A COMMITMENT TO ECONOMIC GROWTH AND RESPONSIBLE STEWARDSHIP OF OUR PLANET. A COMPREHENSIVE STRATEGY WILL BE BUILT UPON A SERIES OF ACTIONS WHICH WILL HAVE A BROAD RANGE OF BENEFITS: FROM CURBING AIR POLLUTION, TO CONSERVING ENERGY, TO RESTORING FOREST LAND -- ALL OF WHICH WILL HELP CURB GREENHOUSE GAS EMISSIONS. AMERICA'S CLIMATE CHANGE STRATEGY INCLUDES ACTIONS THAT WILL RESULT IN U.S. GREENHOUSE GAS EMISSIONS IN THE YEAR 2000 BEING EQUAL TO OR BELOW 1987 LEVELS.

O **SECOND,** THE UNITED STATES BELIEVES THAT RESEARCH AND ACTION MUST PROCEED IN TANDEM. THAT IS WHY WE HAVE ACCELERATED OUR GLOBAL CLIMATE RESEARCH ROUGHLY FIVEFOLD SINCE 1989, AND WILL SEEK \$1.2 BILLION FOR THE COMING FISCAL YEAR. AND THAT IS WHY, HAD THE PRESIDENT BEEN ABLE TO JOIN US THIS MORNING, HE WOULD HAVE BEEN PLEASED TO ANNOUNCE AMERICA'S CLIMATE CHANGE STRATEGY, WHICH INCLUDES BOTH RESEARCH AND ACTION. A SUMMARY OF THIS STRATEGY WILL BE DISTRIBUTED TO YOU TODAY. AS OUR SCIENTIFIC AND ECONOMIC KNOWLEDGE ADVANCES, THE UNITED STATES WILL CONTINUE TO RESPOND.

O **THIRD** AND FINALLY, OUR PURPOSE IN THESE NEGOTIATIONS IS CLEAR. AS PRESIDENT BUSH HAS WRITTEN IN A LETTER BEING DELIVERED TO EACH OF YOU TODAY: "WE ARE PREPARED TO WORK OPENLY, DILIGENTLY, AND RESPECTFULLY TOWARD ACHIEVING THE

GOAL OF COMPLETING A CLIMATE CHANGE CONVENTION IN TIME FOR ITS SIGNATURE AT THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT IN JUNE OF 1992."

NO ONE BELIEVES THAT RESPONSES TO CLIMATE CHANGE WILL BE SIMPLE OR COST-FREE. THE ISSUES INVOLVED ARE COMPLEX AND HAVE MANY IMPLICATIONS FOR OUR CITIZENS AND FUTURE GENERATIONS. YET WE ARE HERE BECAUSE WE RECOGNIZE THE NEED TO PROMOTE GLOBAL ENVIRONMENTAL STEWARDSHIP FOR ALL THE WORLD'S PEOPLES, IN A FORUM THAT IS DEMOCRATIC AND COOPERATIVE.

IT IS THE HEIGHT OF IRONY THAT AS WE BEGIN A CONSTRUCTIVE DIALOGUE ON OUR SHARED ENVIRONMENTAL FUTURE, SADDAM HUSSEIN'S PREMEDITATED AND WANTON RELEASE OF CRUDE OIL INTO THE PERSIAN GULF INFLECTS ENORMOUS ENVIRONMENTAL DAMAGE.

SADDAM'S UNCONSCIONABLE ACT WILL NOT DIVERT US FROM THE TASK AT HAND. INDEED IT ONLY HEIGHTENS OUR RESOLVE. FOR NO NATION OR BLOC OF NATIONS HAS THE UPPER HAND WHEN IT COMES TO THE ENVIRONMENT. EITHER WE ALL WIN OR WE ALL LOSE. LET US WORK COOPERATIVELY AND BE CATALYSTS FOR AN ESSENTIAL KIND OF PEACE-- A PEACE BETWEEN HUMANITY AND OUR PLANET.

TURNING TO THE AGENDA OF THESE NEGOTIATIONS, THE U.S. BELIEVES IN SEVERAL GUIDING PRINCIPLES.

FIRST, OUR EFFORTS MUST BE COMPREHENSIVE IN SCOPE. TWENTY YEARS AGO, WHEN WE IN THE UNITED STATES ENACTED OUR FIRST ENVIRONMENTAL STATUTES, WE FOCUSED ON NARROW ASPECTS OF A COMPLEX PROBLEM. THE CLEAN AIR ACT OF 1970... THE CLEAN WATER ACT OF 1972... THE TOXIC SUBSTANCES CONTROL ACT... THE RESOURCE CONSERVATION AND RECOVERY ACT... ALL ADDRESSED JUST A PIECE OF AN INTRICATE PUZZLE. TOO OFTEN, THESE STATUTES RESULTED IN MOVING POLLUTION AROUND FROM AIR TO LAND TO WATER. WHILE THEY LED TO SUBSTANTIAL SUCCESS IN CLEANING UP OUR ENVIRONMENT, THERE IS A BETTER APPROACH. THE ENVIRONMENT IS HOLISTIC-- A DYNAMIC SYSTEM OF INTERACTIONS BETWEEN LIVING THINGS, THE WATERS, LAND, AND SKIES. AS WE SEEK TO PROTECT OUR ENVIRONMENT, WE MUST DO SO FROM THAT BROAD, COMPREHENSIVE PERSPECTIVE.

SECOND, OUR AGREEMENTS SHOULD BE LONG-TERM AND ADAPTABLE. WE ARE UNITED IN THE BELIEF THAT DESPITE LARGE UNCERTAINTIES, THE POTENTIAL THREAT OF CLIMATE CHANGE JUSTIFIES TAKING ACTION NOW. YET EACH OF US OPERATES IN UNIQUE CIRCUMSTANCES: POLITICAL, ECONOMIC, SOCIAL, ECOLOGICAL. DIFFERENT POLICIES WILL HAVE DIFFERENT COSTS AND BENEFITS FOR DIFFERENT NATIONS. WE NEED AN INTERNATIONAL CLIMATE CONVENTION THAT COMMITS ALL NATIONS TO MEANINGFUL ACTION, YET DOES NOT LIMIT US TO SOME FIXED FORMULA.

LET US REMEMBER THAT THE ACTIONS TO WHICH WE COMMIT OURSELVES WILL NOT OCCUR AUTOMATICALLY OR INSTANTLY. OUR DECISIONS WILL AFFECT HUMANITY FOR DECADES TO COME. HENCE OUR

ACTIONS MUST BE CONTINUOUSLY REVIEWED AND REFINED AS KNOWLEDGE AND CONDITIONS CHANGE. AS PRESIDENT BUSH STATED, "GLOBAL STEWARDSHIP IS A CONTINUOUS PROCESS OF SOCIAL DECISIONMAKING THAT MEETS THE NEEDS OF THE PRESENT GENERATION WHILE EXPANDING THE OPPORTUNITIES OF FUTURE GENERATIONS."

A THIRD ELEMENT OF SUCCESS IN OUR VIEW WILL BE AN INCLUSIVE APPROACH. BECAUSE THE ISSUES WE ADDRESS ARE GLOBAL IN NATURE, OUR ACTIONS MUST BE GLOBAL. WE MUST MAKE EVERY EFFORT TO ENSURE THE FULL PARTICIPATION OF ALL NATIONS IN THESE NEGOTIATIONS. FURTHER, A CLIMATE CONVENTION SHOULD CONSIDER THE FINANCIAL AND TECHNOLOGICAL REALITIES OF ALL NATIONS. AS PRESIDENT BUSH STATED LAST APRIL, "THOSE WHO HAVE ASCENDED THE ECONOMIC HILL MUST BREAK DOWN THE BARRIERS TO PROGRESS AND ASSIST OTHERS NOW MAKING THE CLIMB."

IN THE FINAL ANALYSIS, IT IS PROGRESS THAT COUNTS. PROGRESS THAT WILL RESULT FROM THE PARTNERSHIPS WE BUILD IN THE MONTHS LEADING UP TO THE UNCED CONFERENCE IN RIO DE JANEIRO, JUST EIGHTEEN MONTHS FROM NOW.

ON BEHALF OF PRESIDENT BUSH, WELCOME TO THE UNITED STATES. JUST AS WE HOPE THIS GATHERING WILL PROVE TO BE A PRODUCTIVE START IN OUR COOPERATIVE EFFORTS, SO, TOO, DO WE HOPE YOU WILL HAVE A MOST ENJOYABLE STAY. GOOD LUCK AND GODSPEED.

THANK YOU.



U.S. Department of Justice

Environment and Natural Resources Division

Office of the Assistant Attorney General

Washington, D.C. 20530

January 24, 1991

MEMORANDUM

TO: D. Allan Bromley
Assistant to the President for Science and Technology
Chair, DPC Global Change Strategy Group

FROM: Dick Stewart *D. Stewart*
Assistant Attorney General
Chair, Task Force on Comprehensive and Incentives
Approaches to Climate Change

SUBJECT: Report on the Comprehensive Approach

Attached for review by the Global Change Strategy Group is the Report of our Task Force, "A Comprehensive Approach to Addressing Potential Climate Change." The PCC Working Group on Climate, led by the State Department, has requested that this Report be available for distribution to foreign governments and other interested persons during the negotiations on a framework convention on climate change starting February 4, 1991.

The Report has been reviewed and cleared through a joint circulation to both our Task Force on the Comprehensive and Incentives Approaches to Climate Change, and the PCC Working Group on Climate. Once cleared by the DPC Global Change Strategy Group, this Report will be distributed to the public. In order to distribute it by the first week of negotiations, February 4, 1991, we will need comments and clearance by no later than COB **Wednesday, January 30, 1991**. Please request that any comments be delivered to Jonathan Wiener at fax 514-0557 or phone 514-2744.

The Report draws on the Task Force's "Interim Report" of November 8, 1990, and on the very large volume of work ongoing by various agencies that supports the Task Force's efforts to define and develop comprehensive and incentives approaches. The "Overview: An Outline of Key Points" is a revised version of the outline circulated December 31 by you for review by the DPC Global Change Strategy Group, incorporating comments received during that review and edits for public release.

It has been suggested that Chapter VIII of the Report be removed because the text on emissions trading, though accurate and in the U.S. interest, might in this context imply a willingness to discuss emissions limitations. We believe this question should be decided by the DPC Global Change Strategy Group.

PCC Working Group on Climate Change

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DOJ DRAFT 12/26/90

A COMPREHENSIVE APPROACH TO CLIMATE CHANGE

Briefing Materials for the Domestic Policy Council

Presentation by the Department of Justice,
Environment & Natural Resources Division

on behalf of the

Task Force on
Comprehensive and Incentives Approaches
to Climate Change

January XXX, 1990

- OFFICIAL USE ONLY -

"Comprehensive Approach" described

- o It is an approach to structure consideration of climate change issues on a comprehensive basis. It stands in contrast to the "piecemeal" approach currently dominating the discussion, which focuses narrowly on emissions of one gas, carbon dioxide (CO₂), primarily from the energy and transportation sectors.
- o It considers all of the significant gases that affect climate:
 - Carbon dioxide (CO₂), Methane (CH₄),
 - Nitrous oxide (N₂O), Chlorofluorocarbons (CFCs),
 - Hydrochlorofluorocarbons (HCFCs),
 - Tropospheric Ozone (O₃) and its precursors:
 - Nitrogen oxides (NO_x)
 - Carbon monoxide (CO)
 - Volatile organic compounds (VOCs)
- o It also considers sinks, such as forests, that absorb gases. It focuses on net emissions (sources less sinks).
- o It considers all sources and sinks of the relevant gases, in every sector of human activity:
 - Energy generation, Transportation, Agriculture,
 - Forestry and land clearing, Industry
 - (See Appendix I)
- o It employs a measure, such as an index, of the comparative environmental impacts of the gases. This index reflects the fact that gases vary in their effects on the atmosphere. (See Appendix II.)
 - An index ensures that decisions are not made piecemeal to manage one gas while ignoring others. Some index or weighing system is unavoidable, whether implicit or explicit. A CO₂-only policy implicitly weights the other gases at zero.
 - One possible index is the "Global Warming Potential" (GWP) index, presented in the IPCC Report. The GWP measures the relative "radiative forcing" of each gas over time -- its potential to warm the atmosphere.
 - (The IPCC GWP figures are shown in Appendix II.)

- 2 -

Comprehensive approach has multiple applications

- o Research. Designing research strategies to generate information relevant to all gases, sources, and sinks.
- o Monitoring and Inventories. Calculating current atmospheric currents and net emissions for all gases by nation and sector.
- o "Report cards." Calculating the likely effects on net emissions for all gases of current policy actions.
- o Technology evaluation. Calculating the effects on net emissions for all gases of new technologies and practices. Possible uses in foreign technology assistance, federal R&D funding, assessments of technology choices encouraged by other regulatory programs.
- o Policy choices. Calculating the effects on net emissions of policy actions proposed by others or considered by the U.S.
- o Policy design. Defining any proposed or agreed response measures in terms of a comprehensive approach, accounting for and allowing flexibility among all relevant gases, sources and sinks.

"How to" and "how much"

- o In general, the comprehensive approach addresses "how to," that is, the design of cost-effective responses (including research, technology development, limitations, etc.). It does not directly address the question of "how much" response to potential climate change is desirable; that is the province of overall cost-benefit analysis.
- o The comprehensive approach does shed light on some approaches to the question of "how much," by highlighting the potentially limited environmental benefits and high economic costs of piecemeal measures.

- 3 -

Advantages of a Comprehensive Approach over a Piecemeal Approach

A. Environmental advantages

- o Piecemeal policies have historically proved environmentally ineffective or even counterproductive. The history of environmental policy has been piecemeal; command and control efforts have been aimed at air, water, and land emissions separately. This has led to cross-media shifts in "residuals" (emissions and wastes), moving pollution around without reducing it.
- o This Administration has developed better approaches:
 - multimedia approach to solid and toxic pollutants
 - multipollutant approach to air emissions
 - comprehensive approach to climate
- o Shifting residuals in the climate context: A narrow focus on limiting emissions of one trace gas, or one sector, could induce counterproductive shifts in emissions to unregulated gases and sectors. For example:
 - Piecemeal policy aimed at CO₂ alone could induce fuel-switching from coal to natural gas, because natural gas emits less CO₂ per BTU than coal. But a CO₂-only approach would overlook resulting increased methane (CH₄) emissions from natural gas transmission leaks. If the CH₄ leakage rate is about 6%, all of the CO₂-related reduction in radiative forcing (GWP) from this fuel-switch is offset by CH₄ leaks. Although CH₄ leaks average 1% in the U.S., they are 3% in Australia, where about half the CO₂ savings would be offset. And CH₄ leaks average 5-10% in the Soviet Union and Poland, so a CO₂-only policy applied there could actually increase net contributions to radiative forcing.
 - Piecemeal focus on limiting agricultural CH₄ could induce use of nitrogenous fertilizers that reduce CH₄ emissions per rice yield, but also raise N₂O emissions.

Comprehensive approach ensures that such shifts are accounted for by decisionmakers.

- 4 -

Advantages, continued

- o Inclusion of Sinks. By focusing on "net" emissions, the comprehensive approach fosters sink protection and expansion, such as afforestation and protection of phytoplankton. Benefits include biodiversity, reduced soil erosion, protected food webs.

- B. Economic and social advantages
- o Piecemeal approach is economically inefficient. Piecemeal policy (for example, one that deals solely with CO2 emissions) would exclude policy options that address sinks or other gases and achieve the same environmental outcome at less cost. For example, a policy aimed only at energy sector CO2 would bar potentially less costly abatement options such as afforestation, CH4 reductions, attention to CFC-substitutes, or N2O reductions.
- o Flexibility reduces costs. The costs of different options will vary across nations, so to minimize costs each ought to have the flexibility to build its least-cost policy mix among the gases and sectors.
- o Level Playing Field. A piecemeal approach inevitably favors some nations over others. For example, a CO2-only approach penalizes nations with relatively greater dependence on fossil fuels. A comprehensive approach provides a "level playing field" across nations.

- 5 -

Potential objections to a comprehensive approach

- o "Data and monitoring of sources and sinks are inadequate."
 - We are building better data and monitoring.
 - Employ carefully chosen proxies or surrogates for difficult-to-measure emissions.
 - Design incentives for monitoring improvements, such as offering emissions credit to those who demonstrate better monitoring techniques.
 - The groundwork needed to flesh out a workable comprehensive approach is surely less costly than an ineffective, inflexible piecemeal approach.
- o "The Global Warming Potential Index is uncertain."
 - There is emerging consensus: the scientific fundamentals are sound. (See Appendix II.)
 - Work toward improvements.
- o "Other discrete actions will have already been taken, e.g. a forestry agreement, limits on CFCs in the Montreal Protocol, limits on VOCs."
 - Integration of prior and current actions into comprehensive approach will be appropriate in any case;
 - Comprehensive approach provides the opportunity for integrating domestic actions that reduce net greenhouse gas emissions but are taken for other reasons ("justified in their own right").
- o "CFCs should not be included in comprehensive basket."
 - Comprehensive approach would not allow violation of the Montreal Protocol.
 - Some nations are doing more to reduce global CFCs than others, and their contribution should be recognized.
 - CFC substitutes (HCFCs, HFCs) may be quite important to radiative forcing.
 - Existing reservoirs of CFCs are leaking into the atmosphere, but are not covered by the Montreal Protocol. Giving credit for reductions in these CFCs would provide helpful incentives.

- 6 -

Options for Including a Comprehensive Approach in a Framework Convention.

The convention is not likely to contain emissions limitations obligations. But as described earlier, the comprehensive approach has multiple applications. Each could be incorporated in the convention.

- (1) Research strategy. Pursue scientific and economics research on a comprehensive basis: ensure attention to the sources, sinks, atmospheric properties, and socioeconomic and ecological impacts of all the relevant trace gases.
- (2) Monitoring. Develop comprehensive source and sink monitoring: cooperative international networks measuring emissions and uptake of all relevant trace gases. Create institutions for data sharing, harmonizing methodologies, R&D on new techniques.
- (3) International inventories. Build the capacity to estimate international net emissions of relevant trace gases: baseline levels and changes due to policy actions. Provide for national reporting, workshops to compare numbers and methods.
- (4) Index. Cooperative development and refinement of an index. Create an institutional expert body to conduct regular reassessments and to keep policy makers informed of research developments.
- (5) Technology evaluation. Employ a comprehensive approach to assess any technology transfer and financial assistance activities.
- (6) Ensuring a comprehensive framework policy. Ensure that any policy discussion, any calls for "national plans," or any limitations obligations (if any, whether now or in the future), are defined in terms of a comprehensive approach. This could be required, or at least endorsed, in a convention.
- (7) Advance assurance. Give advance assurance that current actions will receive "credit" against any future limitations obligations, in accordance with a comprehensive approach.
Pros: Helps avoid disincentives to taking actions justified on other grounds; nations may hold such actions in abeyance lest they lose credit for them. Ensures a comprehensive approach to credit for discrete initiatives (e.g. CFCs, forestry, VOCs, and any national actions such as CAA, tree planting, energy efficiency).
Cons: Requires debate over baseline.

- 7 -

Options for International Trading in the Convention. Emissions trading has proved quite successful in the U.S., and is a mainstay of the Administration's acid rain title under the new Clean Air Act. If there is eventual agreement, globally or regionally, on limitations on net greenhouse gas emissions, each participating nation would have an allowance of such emissions. Portions of these allowances could then be traded, both domestically and internationally. Allowing firms or nations to trade any net gas emissions limitations would offer useful flexibility and reduce costs. For example, if the USG provided assistance to Brazil in reducing degeneration, it might receive partial credit (in the form of net greenhouse gas emission reduction allowances) for the resulting reduction in CO₂ and CH₄ emissions. Or, a U.S. firm that invested in construction of a factory to produce energy - efficient refrigerators in China could receive similar credits as a part of its compensation; the U.S. firm could resell the credits to a utility (in the U.S. or elsewhere) constructing a new fossil-fueled generating plant.

Without agreeing to any emissions limitations in a framework convention, the following bases for international trading could be laid:

- (a) "REIOs." Under the Montreal Protocol, "regional economic integration organizations" (REIO) may achieve aggregate compliance; they can reduce CFCs under an REIO-wide "bubble." This notion could be broadened to allow any group of nations, regional or non-contiguous, to work together.
- (b) Joint cooperation. The convention could include general language stating that any obligations under the convention or subsidiary instruments can be met through "joint cooperative arrangements." This would ensure the option of international trading for technology development, emissions limitations, or other obligations.
- (c) Registry. The convention could develop an international information center on trades. The center could initially gather information and provide advice on how to arrange and implement effective trades.
- (d) Financial and technology transfers. The convention could incorporate emissions credits into international technology transfer and financial assistance arrangements. Funds and technology transferred by donor countries, directly or through a global environmental funding facility, could earn credits for the donors corresponding to the net emissions change (calculated in terms of a comprehensive approach) achieved by the transfer. The donor could then submit the credit in compliance with any international limits on emissions that might later be agreed.

APPENDIX I:

Anthropogenic Sources & Sinks of Selected Gases

<u>Gas</u>	<u>Sources</u>	<u>Sinks</u>
Carbon dioxide (CO ₂)	Fossil fuel combustion Land clearing	Forests Grasses Soils Ocean biota & storage
Methane (CH ₄)	Enteric fermentation in livestock Rice cultivation Wetlands Landfills Natural gas drilling, venting, transmission Coal mining Biomass combustion	Atmospheric OH interaction Soil removal
Nitrous oxide (N ₂ O)	Agricultural fertilizers Land clearing	Soil removal
Halocarbons (CFCs and related)	Refrigerants Aerosol propellants Foam blowing agents Solvents and cleaning agents Fire retardants	
Tropospheric Ozone (O ₃)	Precursors: CH ₄ , CO, VOCs, in the presence of NO _x Transport of strat. O ₃ into troposphere	Halocarbon depletion
Carbon monoxide (CO)	Fossil fuel combustion Biomass combustion Precursors: CH ₄ , VOCs	Atmospheric OH interaction
Nitrogen Oxides (NO _x)	Fossil fuel combustion Biomass combustion Agriculture	
Volatile Organic Compounds (VOCs)	Fossil fuel combustion Biomass combustion Industry	Atmospheric OH interaction
Aerosols/sulfates (e.g. SO ₂)	Fossil fuel combustion	

APPENDIX II:

Trace Gas Indices

- o Gases vary by several characteristics:

1. Heat trapping ability ("radiative forcing")
2. Residence time in the atmosphere
3. Reactivity with other gases (which affects both the gas' own residence time and the production of other radiatively active trace gases in the atmosphere)
4. Other attributes

- o The "Global Warming Potential" (GWP) Index calculated by the IPCC reflects the first 3 characteristics of gases:

Gas	Instantaneous radiative forcing per kg	Atmospheric residence years (estimated)	Relative radiative forcing potential over years		
			20	100	500
CO2	1	120	1	1	1
CH4	58	10	63	21	9
N2O	206	150	270	290	190
CFC-11	3970	60	4500	3500	1500
CFC-12	5750	130	7100	7300	4500

(Source: IPCC Scientific Assessment, tables 2.3 and 2.8.)

- o Per unit, CO2 is the weakest of the radiatively active trace gases. It is a feature of the large abundance of current CO2 emissions that CO2 accounts for about 50% of current human contributions to total radiative forcing.
- o Some uncertainties remain in the GWP values, relating principally to the residence times of gases such as CO2 and N2O. The consensus of the Boulder Workshop on GWP Indices in November 1990 was that although these uncertainties require urgent attention, they do not warrant abandoning the index. Moreover, for practical policy purposes, some index is much better than no index; an imperfect index could serve well and then be amended at a date several years later agreed in advance.
- o Time and discounting need further discussion. measures taken today to limit short-lived gases, such as CH4, will provide benefits for much fewer years than index equivalent measures to limit long-lived gases, such as CO2, N2O, and CFC. How should these benefits be compared?

Appendix II, page 2

- o A truly comprehensive "global change index" could incorporate other salient global impacts of the gases in addition to their radiative forcing. These other global impacts include beneficial plant enrichment from CO₂, and adverse stratospheric ozone depletion from CFCs and some of their substitutes. Ignoring such impacts could lead to perverse results, such as limiting warming but inducing other adverse environmental consequences. On the other hand, developing and applying a multiple attribute index would be a challenging analytic and empiric exercise.

APPENDIX III:

Research needed in the short term to support the comprehensive approach. The "Interim Report" of the Task Force on Comprehensive and Incentives Approaches identified tasks needed in the next three months, including:

(1) Index. Develop an improved radiative forcing index and outline a plan for further improvements. Incorporate new research results. Draft a proposal for a standing international expert group, to be established in the framework convention, that would develop the index further and would shepherd it toward accuracy, international consensus, and continuing reassessment in light of new research. Draft talking points on time horizons. Outline a global change index, incorporating salient environmental effects in addition to radiative forcing; provide a rough quantitative estimate of its measure.

(2) Emissions monitoring. Draft a proposal for international emissions monitoring network(s) to cover all gases, sources and sinks. Identify specific techniques to be used (e.g. satellites, ground stations). Highlight gaps in knowledge and disputes over methods. Develop proxies or surrogates where needed.

(3) Documenting environmental advantages of a comprehensive approach. Formulate "crisp retorts" or "zingers" to deflate piecemeal proposals, showing they would have little environmental benefit, or actually be counterproductive. Calculate effects of cross-nation, cross-gas, cross-sector shifts. Collect empirical examples of the environmental backfiring of piecemeal strategies applied to other environmental problems.

(4) Documenting economic advantages of a comprehensive approach. Develop quantitative estimates of the marginal cost of abatement of different gases in different selected nations.

(5) Report card. Update the comprehensive "report card" or "budget" of net index-weighted emissions changes achieved by climate-relevant actions taken for other reasons. Repeat analysis for selected foreign nations.

DOJ DRAFT 12/26/90

MONITORING: ELEMENTS FOR THE CONVENTION**I. Atmospheric Concentrations**

- o Create global concentration monitoring networks for each of the relevant trace gases. Ensure appropriate geographic coverage to measure gradients and distributions. For example, create a Methane Monitoring Network, a VOCs Monitoring Network, and so forth. Each network would consist of agreements by nations to undertake monitoring and share methods and data. Where possible, the Networks would build on existing institutions (e.g. IGBP) rather than create new institutions.
- o Organize data collection institutions and structures to receive, code, interpret and report on data collected by the Networks.

II. Net Emissions: Sources and Sinks

- o Sponsor workshops or research programs on atmospheric chemical reactions of relevant trace gases. For example, a Workshop on Methane Interactions, or a Workshop on HCFC Interactions. The output from the Workshops would help describe how concentrations change (residence times and dynamics), and what gases are indirectly affected or produced by molecules of the subject gas, and hence feed into projections of total warming, calculation of the GWP Index, and consideration of non-warming impacts.
- o Organize efforts to harmonize current emissions monitoring methodologies.

For example, there is much controversy over the proper way to monitor emissions from forestry. At the macro level, Brazil has asserted that its satellites are the only ones capable of estimating forest cover properly. At the micro level, there are differences over the contributions to net carbon fixing of different tree types, tree ages, and forestry practices (through their effects on trees, soil biota, and moisture).

The convention could address these topics and set up workshops, expert panels, and research programs to address them.

- o Organize a thorough study of the carbon cycle (atmosphere-ocean-terrestrial sinks such as forests). This would build on the CEES Global Change group's current effort to understand all carbon processes. This work would generate critical information about, among other important topics, CO2 residence time. CO2 residence time is quite uncertain because each carbon atom cycles in and out of the ocean over 5-10 year periods, but is not fully removed from the cycle for hundreds of years or more. Better understanding of the carbon cycle would help specify the GWP index values relative to CO2 (currently quite uncertain).
- o Create micro-monitoring programs, to match the concentration monitoring programs described above by measuring actual emissions and uptake from surface activities. For example, we urgently need better information on N2O, CH4, and NOx emissions worldwide. An "Agricultural Methane Emissions Monitoring Program," for example, could provide technical assistance, operate a network of experimental monitoring stations (with host nation permission), operate pilot test monitoring stations to gather data on typical agricultural practices where on-site monitoring is impractical or not permitted, etc. A "Soil Net Emissions Project" could be similarly designed. Monitoring could be organized on topical/sectoral, regional or national emissions bases. Ensure coverage of developing country emissions. These programs could also develop a data set of emissions/uptake factors for current and potential technologies and practices, covering all relevant gases, sources and sinks, to be used as proxies or surrogates in estimating difficult-to measure (diffuse or non-point) sources and sinks.
- o National inventories. Build outward from the OECD Inventories project to calculate baseline net emissions inventories for all nations. Invite all nations to regional workshops. Feed the data into institutes where these data can be used in emissions forecasting efforts.
- o Develop new and expanded economic models that overhaul and elaborate current economic models to cover multiple trace gases, multiple sectors, sinks as well as sources, better detail on developing countries, etc.
- o Develop monitoring technology, including remote sensing (satellite observation using lasers, etc.), aerial reconnaissance, on-site instruments, etc. For example, create a Remote Emissions Monitoring Platform, or a Tropospheric Ozone Monitoring Technology Clearinghouse. Award recognition, funding, and/or international intellectual property rights to inventors.

DOJ HOF 12/26

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The New York Times

12/3/90

DUTCH GO ABROAD TO HELP CLEAN AIR

See Higher Value in Helping
Expand Forests in Tropics
and in Aiding Poland

By MARLISE SIMONS

Special to The New York Times

ROTTERDAM, Netherlands — Reaching far beyond the bad breath of their smokestacks at home, Dutch power stations have begun an ambitious cleanup project that involves replanting thousands of acres of forests in the tropics and helping to clear Eastern Europe's choking air.

The power companies argue that they can achieve much faster and more impressive results by combating air pollution in poorer or less developed countries than they can by spending huge sums to yield small improvements in the Netherlands.

Under this unusual plan, the Netherlands Electricity Generating Board will immediately finance a \$35 million plant to reduce the load of sulfur now fired into the air by antiquated power stations in Poland. The board has pledged \$300 million more to restore razed forests in tropical countries over the next 25 years.

In northern Europe, where industry is already aroused by an approaching wave of strict new environmental rules, the Dutch program is the first of its kind. But other responses are coming from companies in Sweden, Denmark, Germany and Britain, where manufacturers will be held more and more accountable for dealing with their own waste.

Companies Spending Millions

As concern for nature is reaching deeper into the region's laws and consumer habits, companies are hiring consultants to adjust their environmental behavior. Many are spending millions of dollars to change the ingredients in their products or developing new lines of goods.

They are also turning to image makers to spread the word. From Belfast to Berlin, shoppers are already being courted with new "green" logos and labels on products that claim to be less destructive or more degradable. Even though the facts behind those labels are not always clear, sales of "green" goods have started to soar.

Consumers in the Netherlands, Denmark and Norway have been told that they must help finance clean air projects at home and in poorer regions abroad.

"It's one of the few options left to a society that keeps demanding more energy," said Irene Carsouw, a spokeswoman for the Dutch electricity board. "We can compensate for pollution somewhere else."

Few other places in the world have as much acid air and filthy river water as the crowded quarters of northern Europe.

Norway Plans 'Climate Fund'

Norway in November announced plans for a new "climate fund" to help poor countries fight their own so-called greenhouse gases, which may lead to warming of the earth.

Prime Minister Gro Harlem Brundtland of Norway said the money for the fund would come from the country's offshore oilfields, which will be expected to pay new "carbon dioxide taxes." Norway's oilfields are among Europe's largest producers of oil and natural gas, which on burning produce carbon dioxide, the most important greenhouse gas.

The Dutch, who are putting together a far-reaching plan to clean up the nation, have not objected to the power companies' program to plant forests in the tropics or to help clean the air in Poland.

Dutch consumers are to pick up part of the cost, which means adding a little less than a dollar a year to the average home electricity bill. The privately owned power companies hope they can also tap some of the \$40 million in taxes that they must now pay the Government for emitting carbon dioxide. The 30 power plants account for one-fifth of the country's total carbon output. They also give off sulphur dioxide, one of the major causes of acid rain.

Removing Most of Sulfur

Miss Carsouw, the electricity board spokeswoman, explaining the Dutch-Polish project, said: "We are already removing 92 percent of the sulfur from our emissions here. By investing \$35 million, we can remove another few percent, some 8,000 tons of sulfur."

But that same investment, she added, will now pay for a desulfurization plant that will remove 45,000 tons of sulfur in Poland, where power stations depend on high-sulfur brown coal.

The Dutch plan to replant more than 300,000 acres of tropical forests is expected to start off in Bolivia, Ecuador and Indonesia, where projects are ready. Talks with other nations are said to be under way. The forests' capacity to take carbon dioxide from the air and transform it into oxygen is supposed to offset the carbon dioxide that will be produced when two new power plants are built near Rotterdam.

Policy Options for Stabilizing Global Climate

RCW

TABLE B-67

CO2 EMISSIONS FROM FOSSIL FUEL (Petagrams C/Yr)

REGION	1985	2000	2025	2050	2075	2100
United States	1.3	1.5	1.8	2.0	2.5	3.5
OECD Europe/Canada	.9	1.1	1.3	1.4	1.6	1.8
OECD Pacific	.3	.4	.4	.5	.7	1.0
Centrally Planned Europe	1.3	1.8	2.0	2.9	4.5	5.7
Centrally Planned Asia	.6	1.0	2.3	3.6	4.4	4.9
Middle East	.1	.2	.5	.7	.9	1.0
Africa	.1	.3	.7	.9	1.2	1.4
Latin America	.2	.3	.9	1.4	1.7	1.8
South and East Asia	.3	.5	1.3	2.1	3.1	4.1
TOTAL	5.1	7.0	11.2	15.6	20.5	25.0

TABLE B-68

CO EMISSIONS FROM FOSSIL FUEL (Teragrams C/Yr)

REGION	1985	2000	2025	2050	2075	2100
United States	51.0	28.0	31.5	32.2	32.5	35.1
OECD Europe/Canada	44.7	37.7	49.3	50.1	49.8	54.9
OECD Pacific	14.1	12.3	16.2	18.1	19.5	22.1
Centrally Planned Europe	31.1	51.9	81.5	106.8	129.0	160.8
Centrally Planned Asia	6.0	10.2	26.9	53.5	91.5	145.4
Middle East	2.9	4.0	10.5	19.7	32.0	50.2
Africa	8.5	14.4	38.8	56.6	70.3	84.1
Latin America	16.3	23.6	49.7	76.0	97.9	125.3
South and East Asia	11.2	15.6	30.7	64.5	113.5	184.9
TOTAL	185.8	197.6	334.9	477.5	636.0	862.7

TABLE B-69

NOx EMISSIONS FROM FOSSIL FUEL (Teragrams N/Yr)

REGION	1985	2000	2025	2050	2075	2100
United States	6.1	6.0	6.3	6.2	6.5	7.2
OECD Europe/Canada	4.6	4.8	5.6	5.9	6.0	6.5
OECD Pacific	1.7	1.8	2.0	2.3	2.6	3.0
Centrally Planned Europe	5.8	7.7	8.5	10.6	12.9	15.2
Centrally Planned Asia	2.6	4.7	10.2	14.3	17.5	19.4
Middle East	.4	.6	1.5	2.3	3.1	4.0
Africa	.8	1.5	3.6	5.2	6.6	7.5
Latin America	1.0	1.6	4.0	6.3	8.1	9.6
South and East Asia	1.3	2.3	5.4	9.5	14.2	19.1
TOTAL	24.2	31.0	47.0	62.7	77.5	91.5

DOT - Cost of FFVs
Robert
586 - 5658 Speir

IPCC - using

NES strategy -

Economic (CEA, Treasury, OMB,) - diff. in econ growth

Technology assumptions - slightly higher penetration of coal



United States Department of State

*Bureau of Oceans and International
Environmental and Scientific Affairs*

Washington, D.C. 20520

November 29, 1990

TO: * WORKING GROUP ON CLIMATE

FROM: OES/EGC - Daniel A. Reifsnyder *DAR*

SUBJECT: MEETING SCHEDULE

In the run-up to the first negotiating session on a framework convention on climate change (February 4-14, 1991, in Washington) we have established the following schedule of meetings for the Working Group on Climate. Meetings may not be necessary on all of the dates listed (to be determined), but the schedule should assist all of us in planning. Please confirm your attendance at the December 6 meeting with Jonathan Pershing by COB Wednesday, December 5. His telephone number is (202) 647-3079

<u>Date/Time</u>	<u>Location</u>
1) Thursday, December 6 (10:00 - 12:00) Note: First hour will be Working Group meeting to begin preparations for negotiations; second hour will be Task Force on Bilateral Cooperation meeting	State - Rm. 1408
2) Wednesday, December 19 (2:00 - 4:00 p.m.)	State - Rm. 3524
3) Thursday, January 3 (10:00 - 12:00 noon)	State - Rm. 1105
4) Wednesday, January 9 (2:00 - 4:00 p.m.)	State - Rm. 1105
5) Thursday, January 17 (10:00 - 12:00 noon)	State - Rm. 1408
6) Thursday, January 24 (U.S. Del) (10:00 - 12:00 noon)	State - Rm. 1207
7) Thursday, January 31 (10:00 - 12:00 noon).	State - Rm. 1105

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A COMPREHENSIVE APPROACH TO **CLIMATE CHANGE**

USING THE MARKET TO PROTECT THE ENVIRONMENT

ENVIRONMENTAL OFFICIALS from around the world are poised to negotiate an agreement that will set the framework for future efforts to address potential climate change. When the talks begin in February 1991, the need for clear thinking on climate policy will be acute.

The likelihood and potential impact of climate change must be considered. The recent First Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) found that increases in the so-called "greenhouse gases," which trap solar energy when it rebounds off the earth's surface, are likely to yield increases in atmospheric temperature, but that major uncertainties frustrate our

ability to forecast the magnitude, timing, or regional patterns of any climate change.

At the same time, the costs and benefits of climate change and of options to limit or adapt to it also must be considered. These are even more uncertain questions on which neither the IPCC nor anyone else has made much progress.

Then, if preventive efforts are deemed warranted—a big "if," given the above uncertainties—the design of any policy steps must be considered. Unfortunately, the tenor of current climate discussions indicates that old mistakes in policy design are likely to be repeated. Proposals to address potential climate change have focused narrowly on immediate, uniform controls on emissions of one greenhouse gas: carbon dioxide emitted by the energy sector. Such piecemeal, command-and-control approaches, mandating centrally specified, inflexible responses to subsets of complex environmental problems, will almost surely deliver, as they have in the past in other contexts, environmentally counterproductive and economically unsound results.

Richard B. Stewart is assistant attorney general, Environment and Natural Resources Division, the U.S. Department of Justice. Jonathan B. Wiener is special assistant to the assistant attorney general. The views expressed herein are their own and do not necessarily represent the views of the Department of Justice or the United States.

BY RICHARD B. STEWART AND JONATHAN B. WIENER

A far better approach would be a "comprehensive" one that addresses the net environmental impacts of all greenhouse gases. Such an approach is essential to understanding climate change and to determining the costs and benefits of policy options. It is also essential to fashioning environmentally effective and less-costly policy measures that nations or the world community may choose to adopt. Any such measures should use market-based incentives, rather than command-and-control methods, in order to achieve environmentally superior results at less cost.

Influences on the Climate System

Potential climate change is an issue of enormous complexity. Any change in global average annual temperature would occur over many years through the workings of very complex natural systems and in turn would affect patterns of local temperature, precipitation, soil moisture, and sea level.

The greenhouse gases (GHGs)—carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), tropospheric ozone (O₃), halocarbons such as chlorofluorocarbons (CFCs), and others—are emitted by many sources. Each gas has a different capacity to trap heat in the atmosphere, called its "radiative-forcing" ability, and each resides in the atmosphere for a different period of time. Together, these factors determine the relative radiative-forcing potentials of the GHGs (see table). Each GHG also has environmental consequences resulting from its direct chemical effects on the atmosphere and on plant and animal life: CO₂ aids plant photosynthesis and water use efficiency, for example, while CFCs deplete the stratospheric ozone layer. One GHG or another is emitted or affected by virtually every ecological, social, and economic activity in every area of the world. The gases are removed from the atmosphere in varying degrees by natural "sinks": CO₂, for example, is removed in the photosynthesis carried on by trees, crops, grasses, and oceanic phytoplankton, and stored in plant material, soils, and the deep ocean.

Environmental policy design must match the ecological system it seeks to address. From the climate perspective, the variable of environmental concern is not emissions of CO₂, or the carbon content of fuels, or energy effi-

ciency. It is the *net emissions (sources minus sinks) of all greenhouse gases, weighted by their relative impacts on the environment*. Any policy response to climate—setting a scientific research agenda, enumerating climate-relevant measures (such as reforestation or eliminating CFCs) justified on other grounds, or adopting GHG limitation measures—must therefore be *comprehensive*, matching the climate system.

Carboncentric Thinking

But those proposing immediate GHG reductions typically focus narrowly on limiting CO₂ emissions from fossil-fuel combustion. Many such proposals are made by nations that would enjoy a competitive advantage under such policies: those that can rely on noncarbon or low-carbon energy sources (such as nuclear, hydropower, or natural gas) or those that expect to conserve energy more cheaply than their trading rivals. But such a narrow focus is not warranted by the facts about GHGs or by sound policy.

First, it is clear that the greenhouse effect cannot be attributed to CO₂ alone. It is portrayed as the chief culprit in potential global warming because, by volume, it has accounted for a large share of the total output of GHGs. But because any policies to limit GHGs must necessarily address future increments of net GHG emissions, it is the comparative impact of additional amounts of each gas that must be addressed. CO₂, molecule for molecule, is the *weakest* of the anthropogenic GHGs. As the relative radiative forcing figures in the table show, a unit of CO₂, its typically long residence in the atmosphere notwithstanding, is the least potent contributor to potential warming. Moreover, because there is already so much natural CO₂ in the atmosphere, the band of the electromagnetic spectrum that CO₂ molecules block is becoming almost fully occluded, creating a saturation effect—a kind of atmospheric law of diminishing marginal returns—which means that the relative radiative forcing of future CO₂ molecules will be even less. Further, CO₂ in the atmosphere is not increasing as rapidly as other GHGs; the atmospheric concentration of CO₂ is increasing at about 0.3 percent per year, CH₄ about 1 percent, and CFCs over 4 percent. (Although the goal of the international treaty to protect the stratospheric ozone layer—the

Gas	Instantaneous radiative forcing per kg of emissions	Atmospheric residence years (estimated)	Relative radiative forcing potential over lifetime*
CO ₂	1	120	1
CH ₄	58	10	21
N ₂ O	206	150	290
CFC-11	3970	60	3500
CFC-12	5750	130	7300

Note: *—Calculated over a 100-year time horizon.

Source: IPCC Scientific Assessment, tables 2.3 and 2.8.

RELATIVE RADIATIVE FORCING OF SELECTED GASES

Montreal Protocol—is to phase out CFCs, their more ozone-friendly substitutes are still likely to be significant GHGs.)

Meanwhile, CO₂ provides significant benefits that the other GHGs do not. CO₂ is the grist of photosynthesis. Higher concentrations of CO₂ in the atmosphere are likely to substantially improve plant productivity and increase the efficiency with which plants use water. The other GHGs confer no such benefits, and some pose serious threats unrelated to possible global warming. CFCs, for example, deplete the stratospheric ozone layer. In order to provide a better guide to policy choices, the radiative forcing index of GHGs could be expanded to incorporate other—positive and negative—environmental impacts of each GHG. CO₂ would receive a credit for enriching plant growth, CFCs a debit for ozone depletion.

In sum, unit-for-unit, CO₂ is probably the most environmentally benign of the GHGs. If the biosphere had to accept any given amount of predicted warming, then on purely environmental grounds and abstracting from the costs of control, it would probably prefer to have the warming due to CO₂ and not to other GHGs. CO₂ is thus the last gas, on environmental grounds, whose incremental additions one would want to restrict. Still, any extensive measures to limit net GHG emissions—even under a comprehensive approach—would probably mean some limits on CO₂, the most-prevalent of the anthropogenic GHGs. Moreover, a full analysis requires consideration of the costs of limitation as well as the benefits. It would be economically and environmentally irrational to focus solely on one GHG in any measures to limit climate change, because the greatest benefit may often be had for less cost by addressing other GHGs.

Focus on the energy sector is likewise inappropriate. Certainly the energy sector produces a large share of global CO₂, carbon monoxide (CO), CH₄, volatile organic compounds (VOCs), and nitrogen oxides (NO_x). But the GHGs arise from a variety of sources in every sector: agriculture, where rice paddies and livestock disgorge enormous amounts of CH₄ and fertilized fields release N₂O; forestry, where tree-cutting and soil disruption liberate about 10 to 33 percent of global anthropogenic CO₂; industry, which emits large amounts of CFCs, VOCs, CO, and NO_x; transportation, which yields CO, VOCs, and CFCs in addition

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to CO₂; and the residential and commercial sector, which produces CO₂, VOCs and CFCs.

And in addition to GHG sources, the GHG sinks deserve serious attention. It is *net* emissions that matter for climate system functions. The net flow of GHGs into the atmosphere is the result of emissions from surface sources and removal by surface sinks, including ocean mixing, oceanic phytoplankton, trees, grasses, soil biota, crops, and tropospheric chemical reactions. Plants remove CO₂ from the atmosphere during photosynthesis; preserving and properly managing forests and other vegetation or protecting phytoplankton from anthropogenic injury can help sequester CO₂ released from surface sources.

The Comprehensive Approach

Any climate policy must be comprehensive to match the diverse character of GHGs, their sources, and sinks. Scientific studies, technology development, enumeration of current climate-relevant actions taken for other reasons, or proposals to limit GHGs should be based on net emissions of all GHGs, sources, and sinks and on weighting GHGs according to an index of their comparative environmental impacts. This comprehensive design would ensure that no important GHG or GHG-related activity is ignored, while providing a guide to addressing the most environmentally significant GHGs rather than fixing narrowly on one gas or sector.

If the strategy is technology development or enumeration of otherwise justified actions, a comprehensive approach is necessary to determine which technologies and actions are climate-relevant. If limits on GHG emissions are deemed warranted, a comprehensive approach would have important economic and environmental advantages. It would allow each nation the flexibility to devise its own cost-effective policy mix. Because the marginal costs of limiting emissions will vary across nations by gas, source, sink, and technique, a piecemeal or uniform approach would impose undue costs on those who could achieve the same environmental objective by less costly means. The flexibility afforded under a comprehensive approach would allow choice among all available response options, ensuring that costs are minimized. For example, the

least-cost policy option for limiting net emissions in one nation may be switching from coal to natural gas, while for another nation it may be changing agricultural practices to reduce CH₄ and N₂O emissions, and for another it may be reducing deforestation and ensuring sustainable forest management. Put another way, reducing emissions of CO₂ from fossil-fuel combustion (or stopping deforestation, or any other single tactic) might be the cheapest way to limit overall net GHG emissions in one nation but the most expensive in another. Rigid, uniform requirements would be economically irrational, needlessly driving up social costs.

The "net emissions" aspect of the comprehensive approach would also provide significant benefits by encouraging sink expansion through expansion of forest areas and preservation and protection of phytoplankton habitats from pollution. In addition to limiting net GHG emissions, these activities could provide other benefits in biodiversity, oceanic food webs, reduced soil erosion, and better timber management.

Anticipating "Unanticipated Consequences"

The comprehensive approach would also avoid a notorious drawback of piecemeal approaches: unwanted shifts to unregulated activities that continue to produce environmental degradation. For example, under a CO₂-only approach, utilities would probably switch from coal to natural gas (methane) because, with current combustion techniques, burning coal produces almost twice as much CO₂ per BTU as burning natural gas. But use of natural gas leads to CH₄ emissions because it leaks from natural-gas mining and transportation systems. One recent study estimates that with a 3-6 percent rate of CH₄ leakage from natural-gas transport, such leaks would fully offset all the CO₂-related radiative-forcing savings from switching from coal to natural gas. Such leakage rates are probably higher than the average in the United States, but may be typical elsewhere. And a swift expansion of natural-gas transport capacity to comply with a stiff CO₂ reduction target could well mean the use of hastily designed new facilities or older facilities in disrepair with leakage rates higher than today's. Hence, the result of

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piecemeal fuel switching could be even greater net GHG emissions than in the absence of the CO₂-reduction rule. Even if the CH₄ leakage rate only offset, say, 50 percent of the CO₂ savings, the CO₂-only policy would be severely undermined. Similarly, a transportation-only policy requiring, say, the use of electric vehicles, could shift production of emissions to the central power stations that recharge the vehicles' batteries. The comprehensive approach, on the other hand, would encompass all relevant emissions and thereby ensure that policies and incentives address the full net GHG emissions inventory.

A different kind of inadvertent shift would attend restrictions on fossil-fuel consumption applied piecemeal to one group of nations (such as OECD countries). If developing countries' net GHG emissions continue to rise at current rates, even radical OECD-only policies will be unable to arrest growth in global emissions. And the OECD nations would most likely respond by limiting imported fuels first, which would lower prices for those fuels on world markets and increase consumption in other nations. Depending on the sensitivity of consumption to prices and the efficiency of fuel combustion in the various countries, total GHG emissions might even rise. Over the slightly longer term, restrictions in only some nations could induce GHG-emitting industries to move to unregulated locations. These concerns indicate the need for comprehensive scope of coverage and international cooperation on any limitations measures.

Applying the Comprehensive Approach

Any framework convention on climate change should promote a cooperative scientific research and reporting agenda that would facilitate the comprehensive approach by examining all GHGs, sources, and sinks. It should also ensure that any future protocol follow the comprehensive approach. The convention could assure that any actions taken by a nation after a chosen baseline date will be credited to that nation's limitation obligations, if any, under a future protocol, relying on a provisional index of relative GHG impacts established at the convention. Without such advance assurances, nations would be hesitant to take even climate-relevant steps that are justified

on other grounds lest they lose credit for such steps when a climate agreement is signed. This fear would frustrate independently desirable policy steps (such as energy conservation or reforestation) while adding to pressure for hasty adoption of a climate protocol.

The major objection that has been raised to the comprehensive approach is that current science is not adequate for monitoring certain sources and sinks, such as nonpoint (diffuse or mobile) sources of CH₄ and N₂O. The objectors say that we should "do what we can now" and wait until later to design a comprehensive approach. The counterargument is that while monitoring such emissions is not easy it is not beyond our reach if we orient current research efforts to support a comprehensive approach. Moreover, our experience belies the suggestion that piecemeal initiatives can eventually be transformed into a comprehensive strategy. Piecemeal measures tend to create vested interests that fight to ensure the perpetuation of their favorite measures. For example, the overbroad Prevention of Significant Deterioration (PSD) provisions in the Clean Air Act limit industrial development in many regions of the United States, often without environmental justification. But other regions oppose relaxing these limits for fear prosperity will shift to those regions now subject to PSD controls. Similarly, any global climate agreement targeted at energy-sector CO₂ limitations would benefit some nations more than others. The favored nations would resist development of a more comprehensive approach that would treat all nations with an even hand. It is vital, therefore, to start with a comprehensive approach at the outset.

The pertinent question is not what is immediately feasible but whether the costs of proceeding with a flawed policy design are less than the costs of doing the necessary groundwork to develop and implement a comprehensive approach. The answer is that we need not wait for perfection; in the interim, proxy-based estimates of difficult-to-measure emissions can be used. A framework convention (or another agreement) can provide incentives for investments in developing or improving the requisite monitoring capabilities, such as by offering credit for national reductions in difficult-to-monitor GHGs upon demonstration of the relevant monitoring techniques to an expert panel.

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Market-Based Incentives

The virtues of market-based economic incentives for environmental protection are increasingly recognized. Fees or taxes, tradeable allowances, and deposit-refund programs have been successful in several important environmental applications, and we are learning how to apply them in others. The tradeable credits program used to phase out lead in gasoline achieved its goal at about half the cost of traditional regulation, saving hundreds of millions of dollars. Deposit-refund programs have aided in reducing litter and recycling beverage containers. Both fees and tradeable allowances are now part of the U.S. program to eliminate CFC use under the Montreal Protocol. And tradeable allowances have been proposed for the acid-rain-reduction provisions of the new Clean Air Act, with projected national savings of \$1 billion annually when compared to a command-and-control program. Meanwhile, we have learned a great deal about the drawbacks of traditional regulatory approaches—the centrally specified, uniform, and rigid edicts of "command-and-control" methods—in terms of their cost, obstacles to innovation, ecological shortsightedness, and legal and administrative burdens.

Market-based incentives respond to market failures such as excessive pollution by harnessing and redirecting market forces to engender socially and environmentally responsible behavior. At the same time, they allow flexibility among regulated firms, promote diverse and cost-minimizing solutions by allowing those who can fix a problem most cheaply to do so, and stimulate efficient resource use and innovation in technologies and practices.

Market-based techniques are especially well-suited to any limitation measures for GHGs that might be adopted nationally or worldwide. Because GHG emissions arise from so many diverse and pervasive sources, the costs of abatement are bound to vary widely among emitters. Market-based mechanisms use that variation to social advantage by imposing a restraint on total emissions—a limit on the net quantity emitted or a fee for each unit emitted—but then letting the market allocate the burden of abatement to those who can most easily shoulder it.

Two main economic instruments have

been suggested for limiting emissions of GHGs: tradeable emissions allowances and emissions taxes. Tradeable allowances would set a total limit on net emissions, issue that sum of allowances to emitters, and let emitters trade them. Those for whom emissions reductions or sink expansions would be relatively more expensive would buy additional allowances, while those who could achieve limitations goals cheaply would sell their extra allowances. Each emitter would try to develop new means of limiting emissions at less cost than its competitors so that it could sell its allowances at a profit. Emissions control, efficient use of fuels and other inputs, and innovation of new control techniques would become profit centers for the emitter. The market would allocate limitations to those who limited emissions at least cost, reducing the overall cost to society.

Domestically, governments could issue allowances for net GHG emissions. Those who were issued allowances could meet their limitation obligations through such steps as energy conservation, fuel switching, reducing CH₄ leaks, planting trees, or contracting for limitations by other regulated firms. Allowances could be made of limited duration, or leasable, to relieve fears of hoarding or other distortions due to exercise of market power. Government clearinghouses, private brokers, and banks would act to facilitate trading among disparate parties and over time.

Any internationally agreed national obligations to limit GHGs could be advantageously reallocated among nations through bilateral or multilateral trades. One nation could satisfy its obligations by investing in response actions in another. For example, Nation A could provide new energy technology to Nation B in return for all or part of the value of B's reduction in emissions. Or Nation C could plant and manage trees in Nation D's territory in return for their CO₂ sink value while offering assistance to D to compensate for the reduction in arable land area. Nation E might earn the opportunity to record certain emissions reductions achieved in Nation F in return for debt forgiveness promised to F. Given significant international variations in marginal costs of limitation, mutually agreed trades would probably enable the world economy to realize substantial cost savings. These arrangements would demonstrate the power of applying Adam Smith's lessons of comparative advan-

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tage to global environmental resources. Such trading in GHG limitations would also serve as a market-based, decentralized vehicle for introducing needed capital and low-GHG-emitting technology into the developing world. Opportunities to obtain valuable emissions allowances by investing in lower-cost net GHG emissions limitations in developing nations (where, for example, energy production facilities do not yet exist) would attract funding from industrialized countries and stimulate innovation of low-GHG technologies useful in developing nations. This framework would obviate creation of a heavily bureaucratized, centralized regulatory authority and technology-assistance fund, with its attendant opportunities for waste and misallocation of benefits.

Emissions taxes for net GHG emissions are another important option. The tax rate could be geared to the GHG index value of the emissions activity. Like emissions trading, emissions taxes offer a cost-effective solution that promotes innovation and efficient resource use. Such a plan could work well within a nation, especially where the emphasis is on specifying the cost of the GHG-limitation program more precisely than the quantity of emissions avoided, or where revenue raising is a major goal. International application of a tax would raise more difficult questions: Would nations cede their sovereignty to an international tax authority? How would the tax be set? How would the potentially enormous revenues raised be allotted and expended?

Conclusion

Experience has shown the inadequacy of employing piecemeal, command-and-control approaches in environmental policy. Reinventing these square wheels in the climate context would surely be ecologically misguided and economically disruptive. A comprehensive approach is the foundation for sound analysis and treatment of the complex climate system and its interactions with socioeconomic activities, whatever level or type of effort nations or the world community may choose to expend on these issues. Should any policy measures be implemented, both a comprehensive design and the use of market-based incentives would be indispensable.





U.S. Department of Justice

Environment and Natural Resources Division

Office of the Assistant Attorney General

Washington, D.C. 20530

October 4, 1990

MEMORANDUM

TO: Members of the Task Force on Comprehensive and Incentives Approaches to Climate

FROM: Dick Stewart *DS*
Assistant Attorney General

SUBJECT: Review Draft of Interim Report;
Research and Analysis Needed in the Next Three Months

1. Attached is a review draft of the "Interim Report" of our Task Force on Comprehensive and Incentives Approaches to Climate. The review draft incorporates your comments following the draft of September 12. This review draft was distributed on Tuesday to the members of the Global Change Strategy Group chaired by Dr. Bromley, and discussed by the Strategy Group at its meeting yesterday.

Please submit any final comments on this review draft by COB Wednesday, October 10. We will then prepare a final draft of the Interim Report and submit it to the Strategy Group.

2. In addition, attached are a short summary list, and a more complete explanatory list, of the high priority research and analysis tasks needed in the next three months, in order to prepare for the negotiations on a framework convention. The tasks in these lists were extracted from the larger Task Force Interim Report review draft. The short summary list was distributed to the Strategy Group yesterday at its meeting. The Strategy Group approved the list and directed our Task Force to complete these tasks (some of which are already under way) within the next three months, organizing small work groups where needed, and to provide a report on our progress before Thanksgiving.

3. In order to accomplish these tasks, we need a group view of what activities are ongoing, what new efforts are needed, and how to organize them quickly to meet the Thanksgiving report schedule. Our Task Force will meet to resolve these questions next Friday, October 12, at 10:00 a.m. in Justice Department conference room 2603 adjacent to my office.

(Submitted to Global Change Strategy Group, Oct. 3)

October 2, 1990

TASK FORCE ON COMPREHENSIVE AND INCENTIVES
APPROACHES TO CLIMATE

RESEARCH AND ANALYSIS PRIORITIES FOR THE NEXT THREE MONTHS

1. Assist State in drafting a possible framework convention that
 - includes a science research section that addresses all GHGs, sources and sinks;
 - provides for an international monitoring agenda for all GHGs, sources and sinks
 - adopts or provides for development of a GHG index based on the radiative forcing and other environmental effects of all GHGs, and possibly incorporating radioactively active trace gases (e.g. sulfate aerosols)
 - provides that any protocol(s) shall, to the extent feasible, be comprehensive.
 - provides that any limitation protocol(s) shall (a) provide for voluntary trading among nations in net GHG reductions (b) provide "credit" for net GHG reductions achieved by nations unilaterally through measures justified on other grounds, or through other international, regional, or bilateral agreements (e.g. forestry).
2. Develop an improved GHG index and an international process for refining the index. Include, to the extent possible, environmental effects other than radiative forcing.
3. Develop a plan for developing an international net GHG monitoring system.
4. Prepare "crisp retorts" to proposals for piecemeal measures by pointing out the environmental and economic drawbacks of agreements limited to particular GHGs, sources and sinks, sectors, or groups of nations, or that use command and control approaches. These also apply to congressional proposals.
5. Develop quantitative analysis and empirical examples to show the environmental and economic advantages of a comprehensive approach.

6. Update "report card" on the contributions to reducing net GHG of US actions being taken on other grounds. Conduct similar analyses for selected other nations.
7. Development of a concise but sophisticated vision of decision making under uncertainty to counter simplistic versions of the "precautionary principle."
8. Develop capacity to analyze economic and environmental costs and benefits of likely proposals by other nations.

Oct. 2, 1990

Task Force on Comprehensive and Incentives Approaches to Climate

Research and Analysis: Work Needed in the Next Three Months

This list extracts from the Task Force's Interim Report (review draft of 10/2/90) the critical high priority, short timeline tasks needed to prepare for framework convention negotiations. These are tasks of high priority needed in the next 3 to 4 months, so that by the end of January 1991 we will be well prepared to negotiate. The U.S. negotiating positions will not necessarily include or refer to all of the items discussed below, but carrying out these tasks will provide information and analyses that will be useful in developing our negotiating positions. In addition, this work may generate information that the Administration may choose to present outside the formal negotiations, such as to other nations, congressional staff, or other interested persons.

(1) Assist State Department in drafting a U.S. version of a possible framework convention; the draft could be offered as a package or as point-by-point modules, could be capable of being introduced in public negotiating sessions, and could be shopped around to other participants in appropriate circumstances. Provide inputs to the State effort that embody a comprehensive approach, that could form the basis for draft text, and that could serve as internal briefing materials to support draft text.

- o The science research section of the convention should take a comprehensive approach, addressing all relevant trace gases, sources and sinks.
- o The convention should provide for an international cooperative monitoring agenda following a comprehensive approach, covering all relevant trace gases, sources and sinks, and covering both emissions and concentrations.
- o It should adopt or provide for the development of a GHG index based on radiative forcing. It could establish an international cooperative approach to reducing uncertainties and science gaps in the index. It should incorporate other environmental impacts of GHGs as practicable. The inclusion of other GHGs (e.g. aerosol particulates such as SO₂) should be considered.

- o It could provide that any future protocol(s) (whether relating to scientific research, quantity emissions limits, emissions fees, best efforts, technology development, or other topics) shall take a comprehensive approach.
- o It could provide for recognition of voluntary reallocations (informal trading) among nations in any net GHG limitations.
- o It could give advance assurance that current and past actions (taken for other reasons but relevant to climate), whether pursuant to treaties (e.g. forestry, VOCs, CFCs) or national policy, will be accorded "credit" under any limitation protocol.

(2) Develop an improved radiative forcing index. The index would be useful for analyzing any steps taken to address net GHG emissions, such as calculating the effect on net emissions of technology development or measures justified on other grounds, as well as potential emissions limitation measures considered by national governments or international accord. The work should:

- o Present robust estimates, and identify and express uncertainties remaining. Uncertainties regarding residence times of certain gases may be especially important.
- o Develop a plan for resolving areas of uncertainty. The plan should identify knowledge gaps and efforts needed to fill them. The plan should also sketch out the institutional means (including international cooperative arrangements) of achieving consensus index values, and adjusting them periodically in light of new science.
- o Advance the state of international understanding and consensus on the approach and the numbers. The estimates, uncertainties, and plan described above should be distributable to the public. Workshops should be held to broaden understanding.
- o Advance multidisciplinary efforts required to address discounting and other topics. Bring scientists and economists together in workshops to discuss these matters.
- o Sketch the design of a global change index (incorporating salient non-warming impacts), and

attempt a rough cut at its estimation, to illustrate at least the order of magnitude of importance of the non-warming impacts. Identify key challenges in developing a global change index.

(3) Design (an) international GHG monitoring system(s). Draft a workplan to guide development of multilateral cooperative monitoring of net emissions. This will be useful for the science of forecasting future concentrations, as well as for tracking any limitations steps claimed to be taken by nations or committed to by international accord. The workplan should make sure to follow a comprehensive approach. It should especially address gaps in current data, e.g. net emissions in LDCs, non-point sources of CH₄ and N₂O, tropospheric O₃ trends, CO₂ sinks, etc. The workplan should be worked out in advance with key cooperating nations on each data gap. It should be ready for multi-national proposal as the core of a monitoring title in the convention. The workplan will need to proceed gas-by-gas in some or many cases; for example, proposing development of an international NMHC (VOC) monitoring network by 1991. Approaches in different nations will need to be harmonized (e.g. reconciling Brazilian methods of remote forestry sensing with others' methods).

(4) Formulate "crisp retorts" or "zingers" to deflate myopic piecemeal proposals. Compile quantitative demonstrations that piecemeal proposals would have little environmental benefit, or actually be counterproductive. The "crisp retorts" could show that, for example:

- o Unilateral or OECD-only reductions would be undercut by: (a) secular growth in emissions elsewhere (e.g., it would take more than a 100% decrease in OECD emissions to stabilize global emissions); (b) depressed world market prices of fuels following reduced demand in industrialized nations, yielding attendant increased consumption elsewhere; depending on the price elasticities of demand and the relative fuel cycle efficiencies in various countries, this could even mean a net increase in emissions; (c) shifts in world trade and industry flight occurring over the slightly longer term, moving GHG-intensive activities to unregulated countries.
- o Policies addressing only one or select GHGs (e.g. CO₂) would be undercut by: (a) secular increases in other GHGs; (b) shifts of economic activities to modes emitting other GHGs. For example, a CO₂-only policy would

likely induce considerable fuel-switching from coal to natural gas, which would yield less CO₂ but increased CH₄ emissions from natural gas transport. Rodhe estimates that at a 3-6% rate of CH₄ leakage from natural gas transport facilities, fully 100% of the radiative forcing reduction from the fuel switching's CO₂ emissions decline would be offset by the concomitant increased CH₄ emissions (assumes a 100-year time horizon and a CO₂-equivalent index value for CH₄ of 10). Average CH₄ leakage rates are reported to be 3% in Australia and 5% or higher in the USSR.

- o Policies addressing only one or select sectors would be undercut by sectoral shifts. For example, under a transport-only policy (such as a high CAFE statute), emissions might shift from fossil fuel combustion in vehicles' on-board engines, to electric cars powered by central fossil fuel utility plants.
- o Policies employing command-and-control strategies, such as mandated adoption of "best available technology," would stagnate innovation and discourage efficient use of resources, leading to increased emissions in the longer run as compared with incentive-based approaches.

Note that these "crisp retorts" would be useful to respond to congressional proposals as well.

(5) Conduct quantitative analysis (and explore empirical examples) of the comprehensive and economic incentives approaches; evaluate whether the approaches are more than intuitively attractive, to the U.S. and others, on economic and environmental grounds. Conduct quantitative tests of the marginal costs and effectiveness of net emissions abatement, and its variations by gas, strategy, sector, nation.

(6) Update the comprehensive "report card": compile the net index-weighted emissions change wrought by relevant U.S. actions, including those that are climate-relevant but justified on other grounds. The compilation should build on the EPA Cost Study and the DOE/NES studies.

Prepare a similar compilation for selected other nations, in order to evaluate the potential cost benefits to other nations of following a comprehensive approach, and in order to assess the utility to the U.S. of expressing U.S. accomplishments on a comprehensive basis (do other nations "score" better on a comprehensive report card?).

(7) Develop a coherent vision of decisionmaking under uncertainty. Develop a concise but sophisticated vision of decisionmaking under uncertainty to counter simplistic versions of the "precautionary principle" (which is sure to raise its head at the convention negotiations, with some proponents suggesting that any conceivable risk warrants immediate costly action). Develop a succinct, readable, intuitively understandable explanation of rational decisionmaking under uncertainty. This explanation could include the point that when uncertainties about the causal relationships, and the best variables for policy manipulation, are large, early action can actually increase environmental damage (and some examples of such miscues). These points dovetail neatly with an explanation of the value of acquiring additional information, an issue that could be critical in the defense of the comprehensive approach against objections that current science is inadequate. (This task is not explicitly identified in the Interim Report of the Task Force, but draws on both the Interim Report and the CEES Ad Hoc Economics Task Force agenda being developed.)

(8) Assess others' proposals. Develop quantitative cost and benefit (effectiveness) estimates for the several specific policy proposals that have been floated. These include proposals to limit CO₂ only (including stabilization of CO₂ emissions, a 20% reduction of CO₂ emissions, a limit of 2 tons of carbon emitted annually per capita, a global carbon tax); New Earth 21; policies covering all GHGs, or all GHGs except those covered under the Montreal Protocol; sources only, point sources only, all sources and sinks, or sources and terrestrial sinks only; all sectors, or certain sectors (e.g. energy, industry, transport, agriculture, forestry), etc.. Develop the capacity to produce prompt analyses of proposals that may be floated in the future.

10/2/90
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Task Force on Comprehensive and Incentives Approaches to Climate

**Interim Report:
Research and Analysis to Support the
Comprehensive and Incentives Approaches**

October 2, 1990

Introduction

This Administration has developed new approaches to the design of potential climate change policy, the "comprehensive" and "economic incentives"¹ approaches. The United States first clearly presented these approaches to the Intergovernmental Panel on Climate Change (IPCC) by letter in December 1989. They were presented more fully through an "Informal Seminar" for the IPCC Response Strategies Working Group (RSWG) officers in February 1990, accompanied by a booklet of Discussion Papers that have since been widely distributed. The new approaches have been reflected in U.S. positions in the IPCC and now in the IPCC report itself, and in several speeches, including the President's April 18 closing remarks to the White House Conference on Science and Economics Research relating to Global Change, and his July 11 news conference following the Houston Economic Summit meeting.

The discussion to date has largely been of a conceptual nature. Work must now be done on the practical workings of these approaches, and to the research and analysis that would be needed to assess their utility and to support their implementation. This Task Force was organized in May 1990 to specify, encourage, and coordinate this work. The Task Force is an interagency effort chaired by DOJ and involving representatives of numerous agencies, including CEA, CEES, CEQ, DOC/NOAA, DOE, DOI, DOJ, EPA, NASA, NSF, OPD, OSTP, State, USDA, USTR, Treasury, and WH Counsel. This "Interim Report" is provided to identify the research and analysis needed, the current Administration efforts

¹The "economic incentives" approach was originally focused on emissions trading, but has since been broadened to encompass other market-based economic instruments, including emissions taxes.

in that direction, and the further work required. Work is needed in several scientific, economic and institutional research areas that bear on or underlie these approaches, including efforts to quantify sources and sinks of multiple greenhouse gases and fill gaps in information on those sources and sinks, to quantify the relative environmental impacts of these gases, to compare the cost-effectiveness of these approaches and their alternatives, and to develop institutional arrangements that could translate these approaches from concept to practicality. In light of the plethora of upcoming discussions, workshops, conferences, international meetings, ministerial conferences and full negotiations -- including the first session of negotiations on a framework convention on climate change, to be hosted by the United States in February 1991 -- prompt attention to these topics is needed to prepare U.S. representatives for effective participation and to assess choices the U.S. may need to make in responding to others' proposals or putting forward its own.

Policy context

These approaches address the "how to" question -- how to design any policy that might be adopted to respond to potential climate change. Their principal aim is to improve the framework of policy analysis and the cost-effectiveness of any proposed policy choice. They do not address the larger cost-benefit question of "how much" policy action should be taken -- what level of social investment, if any, is warranted by risks of potential climate change. The work of this task force does not imply that a choice has been made to implement some policy action.

Furthermore, the "comprehensive" and "economic incentives" concepts are "approaches" or heuristics that offer insight into any discussion of response strategies for potential climate change. The utility of these approaches is not limited to the design of emissions limitation policies. Whether the strategy is pursuing scientific research, promoting new technology, enumerating the measures justified on other grounds that also have potential climate benefits,² or designing actual

²The major uncertainties surrounding potential climate change, potential response strategies, and the costs and benefits of both, have suggested a strategy of pursuing those policies which are justified on other (non-climate) grounds yet which also help to address potential climate change. More precisely, these are climate-relevant policies pursued in the face of uncertainties about predicted climate change which are so great that the present expected loss due to climate change (and thus the expected climate-related benefits of the policy) cannot confidently be said to exceed a de minimis level. Examples include emissions-limiting or adaptive steps taken for non-climate reasons, such as phasing out CFCs, afforestation, improving energy efficiency, and developing more drought-resistant strains of crops. Other examples could include

emissions limitations policies (whether domestic or international), these approaches suggest the desirable breadth, emphasis and direction of the strategy. The "comprehensive" and "economic incentives" approaches to potential climate change policy were originally developed in response to the piecemeal (CO₂-focused), command-and-control regulatory approach then dominating the discussion in the IPCC, but the approaches apply to the full array of policy types and options. And they apply to domestic as well as international discussions.

For example, a nation following the strategy of enumerating climate-relevant measures justified on other grounds could use the comprehensive approach to calculate the aggregate impact on net greenhouse gas emissions made by its various measures. A framework convention on climate change could take a comprehensive approach to the cooperative scientific and economic research to which the parties commit, including the development of international monitoring networks, as well as to any national emissions reporting, or to credit to be given under any future obligation for nations' current voluntary emissions-limiting activities. An economic incentives approach could be applied to adaptation measures desirable in long-range investments, such as coastal construction or water use planning.

Summary of the Approaches

The two approaches are compatible, but need not be employed together. Both approaches offer the possibility of designing environmental policies that achieve goals at lower cost and that heighten the possibility for diverse, innovative, flexible, and cost-effective responses.

Comprehensive approach. The "comprehensive" approach seeks to address all the important contributors to potential climate change, in contrast to a piecemeal focus on CO₂ from the energy sector. It therefore addresses all radiatively active trace gases (RATGs), primarily consisting of the greenhouse gases (GHGs), and their sources and sinks. GHGs include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halocarbons such as chlorofluorocarbons (CFCs) and related substances (HCFCs, HFCs), and tropospheric ozone (O₃), whose precursors include oxides of nitrogen (NO_x), non-methane hydrocarbons (NMHCs) (also referred to as "volatile organic compounds," VOCs), and carbon monoxide (CO).³ Different RATGs arise from different sources and are

³Other RATGs affect the radiative balance of the atmosphere, but unlike GHGs, their main influence is not through absorption of energy reradiated from the Earth's surface. Aerosol particulates such as sulfur dioxide (SO₂), which generally

(continued...)

removed from the atmosphere by different sinks, yielding a "net emissions" budget. Different RATGs have different impacts on the environment; for example, each gas has a different ability to trap certain radiated energy ("radiative forcing") or to reflect it. In order to relate the comparative environmental impacts of the various RATGs, the comprehensive approach employs a parameter or "index" that calculates the relative contribution of increments of each gas to physical effects, such as radiative forcing, used as proxies for global externalities. The comprehensive approach thereby avoids ignoring the important gases that would be omitted from a CO₂-only approach, and avoids ignoring important sources and sinks that would be omitted from an energy-only approach.

As a means of developing an agenda for science and economics research, such as research on the likelihood or impacts of potential climate change, the comprehensive approach suggests the scope of the research agenda: the range of relevant inquiry, the gases and sectors relevant as inputs to economic models of RATG emissions, and the relative environmental externalities (both negative and positive) related to emissions of each gas.

As an approach to technology development, the comprehensive approach assists in identifying and comparing the relative importance of technologies and practices affecting potential climate outcomes.

As a means of enumerating climate-relevant measures justified on other grounds, the comprehensive approach provides a metric for identifying and assessing the policy actions that are relevant in the climate context. It could form the basis for calculating the aggregate impact of various such measures on a nation's net RATG emissions.

As an approach to emissions limitation rules or obligations, the comprehensive approach provides an environmentally coherent and least-cost design for limitations policy. A piecemeal approach, focused on one gas (e.g. CO₂) or one sector (e.g. energy), would omit salient RATGs, sources and sinks. By aiming narrowly, it could very well induce unintended shifts of economic activities to unregulated modes that offset or even increase emissions of RATGs, much as focusing on air emissions alone can shift pollutants to toxic solid sludge discharges. For example, focusing on CO₂ alone could induce fuel-switching from high-CO₂ coal to lower-CO₂ natural gas, meanwhile leading to increased emissions of CH₄ from natural gas

³(...continued)
reflect insolation and thus may exert a net cooling influence, are RATGs but not GHGs. A fully comprehensive approach would encompass all such RATGs.

transmission leaks. The comprehensive approach cures these defects of a piecemeal approach. It also allows the flexibility to choose the least-cost mix of policy options yielding the desired overall RATG limitation. And, by addressing "net emissions," it encourages sink enhancement such as through afforestation or safeguards against pollution of oceanic phytoplankton. The comprehensive approach can be applied to a variety of emissions limitation measures,⁴ including emissions taxes and emissions trading, and including both domestic and international measures. If applied internationally, it has the additional benefit of affording each nation the flexibility and discretion to decide the mix of domestic policies regarding the array of gases, sources and sinks that that nation determines would best accomplish policy goals in light of its unique social, economic, cultural and institutional circumstances.

Economic incentives approach. The "economic incentives" approach similarly applies to a variety of policy options. In the emissions limitation area, it encompasses the panoply of market-based economic instruments, including emissions trading and emissions taxes, imposed to force internalization of the external environmental costs accompanying emissions. It includes the use of incentives to promote innovation in technologies and practices, and addresses adaptation as well as emissions limitation. These incentives could be applied domestically or internationally.

As one example, application of emissions trading to emissions limitation obligations would allow those emitting a substance to achieve compliance with limits on such emissions by voluntary agreements to reallocate emissions among individual emitters so long as the aggregate output did not exceed their overall limit. Thus, reductions would be obtained most at those places where reductions cost least. This could be accomplished by authorizing informal reallocations among emitters, or by formally issuing "allowances" and then authorizing a market in the allowances. Experience with emissions trading in the U.S. indicates that it can achieve environmental quality goals at substantially lower cost, and therefore could be of use to nations domestically as they implement any limits on greenhouse gases. Several U.S. applications of emissions trading have been highly successful, such as the phasedown of lead in gasoline; some others have been instructive of the limits of emissions

⁴In light of the relative weighting of the various RATGs according to their environmental externalities and the flexibility afforded to choose a least-cost mix of measures, it is possible that the comprehensive approach could achieve an aggregate net RATG emissions limit by restricting emissions of some gases while allowing emissions of other gas(es) to rise.

trading, especially when it is applied in the context of other regulatory restrictions on emitters. Allowing emissions trading among nations -- probably initially as informal reallocations accomplished through bilateral national accords -- could similarly be advantageous in the context of any international efforts to develop new technologies or limit emissions.

Emissions taxes would in theory also produce least-cost results. In general, while emissions trading provides more certainty about the quantity of emissions limitation achieved, emissions taxes provide more certainty about the cost imposed on emitters. Domestic use of emissions taxes could be apt where certainty as to cost is more important, or where revenue raising is an important goal. Imposition of international emissions taxes could raise additional institutional, political and sovereignty concerns -- such as whether nations would cede their sovereignty to an international tax authority, how the tax would be set, how it would be made equivalent across economies, and how the potentially enormous revenues raised would be allotted and expended -- that would probably not attend informal bilateral international emissions trading or domestic taxes.

As another example, market mechanisms could be used to encourage efficient adaptation practices. Long-range investments, such as coastal construction or water use planning, might, because of market failures or other institutional failures, be undertaken without giving appropriate weight to any climate change risks (e.g. rising sea levels or shifting precipitation). Such failures might be addressed by informational or incentive-based policies, such as by requiring coastal construction to purchase subsidence insurance, or by fostering a market in water resources that provides incentives for efficient use and long-range risk management.

Research and Analyses

The remainder of this Interim Report describes the research and analysis tasks needed to develop and support the comprehensive and incentives approaches. Our interagency task force has endeavored to identify all of the current agency activities related to each task, although we expect to learn of additional activities as this report is shortly completed.

A companion report being prepared jointly by the CEES' two working groups, Global Change and Mitigation & Adaptation Research Strategies, titled "Research in Support of a Comprehensive Approach to Trace Gas Emissions" (draft 10 September 1990), provides substantial additional detail on the ongoing scientific research relevant to these approaches and the research needed in the future.

Priorities and Timelines

For each task described below, our interagency task force has suggested a priority value and a timeline on which work could and should be completed to be most useful. The suggested relative priority is identified for each task as "high," or "medium," with the understanding that this list is itself a capsule summary of the highest priority items and does not mention numerous tasks judged to be somewhat relevant but not warranting inclusion here.

A time horizon of 3 months, 18 months, or 5 years is typically suggested for each task.⁵ The timeline developed is a combination of the practical pace of research, which suggested a breakdown of tasks into very short-term (3 months), near-term (18 months), or longer-term (5 years) horizons for each task; and the pace of international discussions, which suggested milestones at January 1991, the eve of the first negotiating session on a framework convention (3 to 4 months), June 1992, the target signing date for the convention (roughly 20 months), or 1995, the tentative time for the next full IPCC report (5 years).

The priorities and timelines suggested for each task are suggestions, and we anticipate further discussion and revision on these points.

⁵For certain tasks the timeline is different due to particular scheduling dates; for example, the Second World Climate Conference will be held at the end of this month.

Research and Analysis Underlying the Comprehensive Approach

I. Measuring and Monitoring Atmospheric Greenhouse Gas (GHG) concentrations

Any environmental impacts resulting from GHGs would be associated with changing actual concentrations in the atmosphere, not emissions per se. The comprehensive approach underscores the necessity of gathering data on atmospheric concentrations of all relevant GHGs. Over the last decade much work along these lines has already been undertaken or accelerated, including (i) direct measurement through ground station, aerial, and satellite observation of atmospheric (tropospheric and stratospheric) concentrations of several trace gases (chiefly CO₂, CH₄, N₂O, O₃, and CFCs), and (ii) sample records of past climate change found in ice cores, tree rings, and other sites. Measuring and monitoring past, current and future concentrations, temporal and spatial (e.g. vertical) distributions, chemistry, removal, and other dynamics of GHGs will remain an essential function under a comprehensive approach.

-- Current Administration efforts:

- Under the U.S. Global Change Research Program, several CEES agencies are conducting relevant research. For example, DOE, NASA, NOAA and NSF are conducting or will soon conduct direct measurement of atmospheric concentrations and distributions of CO₂, CH₄, N₂O, tropospheric O₃, CFCs, CO, NO_x and NMHCs. NASA, NSF and DOI are studying sample records of CO₂ and CH₄ in ice cores and tree rings. NASA and NOAA conduct direct observations of stratospheric O₃ and related substances. EPA monitors ambient concentrations of NO_x, O₃, NMHCs, SO₂, and CO. Internationally, the United States participates in the work of the World Meteorological Organization (WMO), the World Climate Program (WCP), the International Geosphere-Biosphere Program (IGBP), and many other monitoring efforts.

-- Future work:

- Ensure coverage of all relevant RATGs. Priority: high. Timeline: continuous.
- Advance the comprehensive approach in any framework convention on climate change. The science research section of the convention must address all the relevant RATGs. It should build networks of cooperative monitoring among nations. Priority: high. Timeline: 3 months to 18 months.

- Advance the comprehensive approach in the Second World Climate Conference. Priority: high. Timeline: 1 month and thereafter.
- Advance the comprehensive approach in the World Climate Program. Priority: high. Timeline: 1 month and thereafter.
- Ensure coverage of relevant temporal and spatial distributions.
- Advance understanding of chemical interactions among trace gases.
- Advance understanding of quantitative link between trace gases and radiative forcing.

II. Impacts of RATGs: Comparative Indices

Changing concentrations of RATGs in the atmosphere are of interest because those gases may yield environmental impacts on societies and ecosystems. Different substances in the atmosphere have different environmental impacts; it goes almost without saying that the environmental impacts of atmospheric oxygen, water vapor, and CO₂ are quite varied, and are believed to be fundamental to the present habitability of the planet. Incremental changes in concentrations of trace gases such as GHGs will similarly have various impacts depending on the particular gas at issue.

(A) Radiative forcing index

In the climate change context, the principal impact of RATGs under study has been radiative forcing. Radiative forcing is not the ultimate environmental impact of actual concern to societies and ecosystems; it is rather an intermediate physical effect that serves as a useful proxy or metric for assessing the impacts of different RATGs on the potential for warming-induced climate change, including atmospheric temperature change, changing precipitation, changing soil moisture, sea level rise, and temporal and regional variations, all of which in turn could affect biological and other systems. Molecules of different RATGs have different radiative forcing properties, and estimates of the relative radiative forcing of incremental amounts of GHGs can provide a common scale along which to compare the gases. A comparative parameter of relative radiative forcing, sometimes called a "global warming potential" (GWP) index or an index of "CO₂ equivalence," has been developed by several scientists. The index incorporates the instantaneous radiative forcing of each type of molecule, its dissipation function and hence its typical residence time in the atmosphere, and the discount rate applied

or the time horizon over which the forcing function is integrated.

-- Current Administration efforts:

- Considerable work has been done on the relative radiative forcing of many RATGs. Estimates of instantaneous radiative forcing, derived from laboratory tests of molecular properties, are well established, as are residence times for several RATGs.

Work in this area has been done by NASA, NOAA, NSF, EPA, and DOE, and has been reviewed and reported by IPCC WG I.

-- Overview of needed work:

Priority: In general, this task is extremely urgent, as it constitutes the technical focal point of the comprehensive approach.

Timeline: Current work on relative radiative forcing is very active; the science is maturing; and robust, reliable, consensus estimates will likely be ready in the near term (6 to 18 months), though with continued uncertainties on specific aspects.

-- Future work:

- Convene international workshop(s) to discuss current work and needed improvements, to build understanding among diverse and representative experts, and to encourage multidisciplinary efforts. EPA, NOAA and NASA are jointly planning to host such a conference in November 1990. Priority: high. Timeline: 3 months.

- Harmonize various quantitative approaches and extend international understanding of indices. Priority: high. Timeline: 3 to 18 months.

- Improve accuracy of dissipation functions and hence of estimated residence times of RATGs. Scientific uncertainties in the current estimates remain surrounding the residence time of CO₂, due to complications in the carbon cycle and uncertainties in CO₂ sink removal processes. Atmospheric chemical reactions involving other gases, such as CH₄ and precursors to tropospheric O₃, complicate estimates of their residence times. Recent work at NOAA is substantially improving estimates of the dissipation rate and residence time of CH₄. As work is ongoing, uncertainties in best estimates can be expressed and revised. Priority: high. Timeline: 3 months to 5 years, varying by gas.

- Incorporate indirect effects attributable to various gases' atmospheric reactions. Certain trace gases react to form other radiatively important trace gases,

or react with substances that would otherwise affect RATG abundances. Much of this work has already been conducted, hence: Priority: medium. Timeline: 18 months to 5 years, depending on gas.

- Take account of "saturation" effects. Radiative forcing by each RATG occurs within a different segment of the electromagnetic spectrum; as that segment or "band" becomes occluded, additional increments of the gas have diminishing marginal radiative forcing impacts. Radiative forcing estimates thus depend on, and need to be expressed in terms of, projected concentrations of relevant RATGs. Much of this information is already available and needs to be incorporated into expressed estimates. Priority: medium to high, depending on significance of the effect for each gas. Timeline: 18 months.

- Take account of the implications that vertical and other distribution of RATGs in the atmosphere may have for calculated index values. This factor is quite important for O3 and its determinants -- CH4, CO, NOx, NMHCs. Priority: high for relevant gases. Timeline: 18 months.

- Improve use of discount rates/time horizons. IPCC WGI expresses GWPs in three selected time horizons; analysis is needed of which of these three horizons, or which other horizon, is appropriate for policymaking. More broadly, better understanding is needed of the scientific and economic basis for choosing different discount rates. Priority: high. Timeline: 3 to 18 months.

- The indices calculated to date have often focused on GHGs and omitted other RATGs. Assess implications of including other relevant substances, such as anthropogenic aerosol particulates (e.g. SO2), in the index. Priority: medium. Timeline: 3 to 18 months.

- Develop institutional mechanisms for adopting a consensus index and adjusting it to new research results. Because uncertainties remain in certain aspects of the index, index values may change as new scientific information is discovered. If an internationally agreed index is used as a tool for design of national policy portfolios to limit net index-weighted RATG emissions, changes in the index values could mean changes in the costs to each nation of its policy package. Mechanisms should be developed for giving advance indication of index uncertainties and likely changes in the index, incorporating new scientific information, and smoothing transitions to new index values. Such mechanisms could include objective science panels and periodic reassessments. Priority: high. Timeline: 3 to 18 months.

(B) Global change index

As indicated above, radiative forcing is only an intermediate physical effect of trace gases, and is really a proxy used as a common metric to compare diverse RATGs.⁶ But RATGs have multiple attributes; they yield other, non-warming environmental impacts of global and local significance which may be more important (in magnitude, timing, or other features) than their contributions to radiative forcing. For example, CO, NO_x, urban O₃, and SO₂ are reactive and/or toxic; CFCs and related substances deplete the stratospheric ozone layer; higher CO₂ concentrations increase plant photosynthesis and increase plants' water use efficiency. Optimal policy choices would entail developing a comparative index that incorporates the full externalities (social and ecological costs) imposed by increments of each RATG. Without such a "complete" index, a simple radiative forcing index could provide signals or incentives that yield desirable changes in aggregate radiative forcing but undesirable changes in other impacts; in other words, significant externalities will remain uninternalized.⁷

At the same time, a fully "complete" index poses quite difficult analytic and technical problems. Data are not adequate on important aspects of the magnitude and variations of the diverse impacts; for example, data are lacking on the effects of ozone depletion on UV-B irradiance, and on the effects of changes in UV-B irradiance on biota. Comparing the dissimilar warming and non-warming impacts on a common scale, something like comparing apples and oranges, is a challenge requiring serious analytic efforts.

A somewhat more realistically achievable index would incorporate only the key "global change" attributes of each RATG, namely their radiative forcing and the other salient non-warming global impacts of GHGs, such as the direct effects of CO₂ on vegetation and the ozone depletion impacts associated with CFCs and other halocarbons. Essentially local attributes of the

⁶Measurement of the ultimate impacts of warming itself on biological and other systems, though critical for assessing the costs and benefits of climate change, are not incorporated into the radiative forcing index because such impacts stem from warming generically, and do not vary depending on the type of gas enhancing the warming.

⁷It is worth noting that, in contrast to the warming-specific term GWP, the phrase "CO₂ equivalence," though unfortunate for its focus of attention on CO₂, does offer the opportunity to introduce non-warming effects into the generic concept of "equivalence."

gases, such as their toxicity, would be left to local policy strategies. This "global change" index would capture the main global externalities associated with the gases, providing significantly more optimal policy signals than an index limited to radiative forcing. It would nonetheless require effort and time to construct.

The desirability of a "global change" index faces a dilemma: pushing too hard for a more complete index could undercut the legitimacy of the radiative forcing index, leading to the latter's disparagement or rejection by other nations, or perhaps to the view that one must wait years for a more complete index. This in turn could encourage the reinvigoration of gas-by-gas policy proposals. A two-pronged effort is therefore needed, to build, improve and promote the radiative forcing index, and at the same time to work on a global change index without undercutting the radiative forcing index.

-- Current Administration efforts:

- Conceptual thinking about design of a global change index. (DOJ, USDA)
- Efforts to quantify direct environmental impacts of CO2 enrichment, chiefly its impacts on agricultural and forestry output, and on water resources. (DOE, USDA, DOI, EPA, NSF). These efforts are high priority in any event.
- Efforts to quantify environmental impacts of stratospheric ozone depletion and resultant UV-B irradiance due to halocarbon emissions, such as impacts on agriculture, phytoplankton, and cancers. (USDA, EPA). These efforts are high priority in any event.

-- Future work:

- Address technical and analytic issues in a global change index. Whereas the common proxy or metric used in current indices is radiative forcing, a global change index would require a common metric among the various warming and non-warming impacts. It would also require application of discount rates because different impacts may occur at different times; for example, CO2 enrichment will likely occur much sooner than any observed warming due to CO2. (DOJ, USDA, DOI). Priority: medium. Timeline: 18 months.
- Undertake preliminary design and rough quantitative estimate of a global change index, in order to assess the difference between the relative RATG values obtained in a global change index versus a radiative forcing index. This effort would also indicate whether a global change index is sufficiently different to be worth developing. Priority: medium. Timeline: 3 to 18 months.

- Improve understanding of direct environmental impacts of CO₂ enrichment, including the impact of CO₂ in concert with changes in other environmental variables such as temperature, moisture, and other pollutants. (DOE, USDA, DOI, EPA, NSF). Priority: high. Timeline:
- Improve understanding of impacts of ozone depletion, including measuring UV-B irradiance and assessing impacts of UV-B radiation on biological systems. (USDA, EPA). Priority: high. Timeline:

III. Measuring and Monitoring net GHG emissions

Assessment of current and future net emissions is critical to the task of predicting the contribution of net emissions to atmospheric concentrations and hence to forecasting potential climate change, regardless of whether any emissions limitations are ever adopted.

The comprehensive approach emphasizes attention to all RATGs, sources and sinks. Baseline data on all of these is not always currently available. In addition, much of the data that are available derives from estimates using data on inputs (e.g. fuel quantities) and knowledge of or assumptions about input-output ratios associated with technologies or practices. Better measurement, forecasting and actual monitoring of net RATG emissions is suggested by, and needed to support, the comprehensive approach.

The ability to better monitor future emissions could also be useful in verifying the implementation of limitation actions and in assuring others' compliance with their claims and with international obligations. This is true of domestic limitations rules as well as international obligations; if a domestic GHG emissions limitation policy is to be effective and, in particular, is to employ performance standards rather than technology-based standards, it will require sound emissions monitoring techniques.

(A) Measuring net GHG emissions

-- Current Administration efforts:

- Numerous agencies collect and analyze data on various gases, sources, sinks, sectors, and industries, and thereby measure emissions from a variety of sources (e.g. energy utilities, mobile sources, land use, agriculture) and uptake by a variety of sinks (e.g. oceans, forests, soils, grasses).
- Efforts are underway to assemble "inventories" of net

emissions of GHGs for many nations,⁸ chiefly EPA's analysis of CO₂, CH₄, CFCs, HCFCs, N₂O, CO, NO_x, and NMHCs for the US and other nations.

- Data are generally adequate on US and other industrialized nations' emissions of GHGs from fossil fuel combustion (generally measured by data on fuel inputs and knowledge of typical combustion techniques), and on world emissions of halocarbons (generally measured by production, consumption and storage rates).

-- Future work:

- Ensure that measurement covers all relevant GHGs, sources and sinks. Priority: high. Timeline: continuous.

- Improve data on other nations. Data on developing nations are particularly scant. The framework convention could call for development of information on all nations, including through a network of cooperative international measuring. Priority: high. Timeline: 18 months to 5 years.

- Develop technologies for measuring net GHG emissions, including direct observation and remote sensing. Priority: medium. Timeline: 18 months to 5 years.

- Develop a data set of emissions/uptake factors for current and potential technologies and practices, covering all relevant gases, sources and sinks. Priority: high. Timeline: 18 months.

- Develop practical proxies or surrogates, such as fuel or fertilizer input data coupled with assumed output rates (e.g. combustion or cultivation techniques), or acreage or livestock data coupled with assumed output rates, to generate emissions factors to assist in measuring emissions. Ensure that measurement uncertainties and assumptions, and use of

⁸ Efforts outside the government include: OECD project, soliciting data from member states on all GHGs; WRI project (in conjunction with UNEP/UNDP) on all nations' net emissions of CO₂, CH₄, CFCs; Harvard Kennedy School survey of many nations' emissions of CO₂ and CFCs.

proxies/surrogates, do not distort policy responses.⁹
Priority: high. Timeline: 18 months.

- Improve understanding of the processes involved in natural emissions and sink uptake, and how these activities might be influenced by climate change.

Priority: high. Timeline: 3 months to 5 years.

- Ensure that data presentations are comprehensive, e.g. avoid CO₂-only or fossil fuels-only charts in IPCC, NES, OTA, and other reports except as adjuncts to complete GHG presentation. Priority: high. Timeline: continuous.

- Ensure that data presentations include the scientific uncertainties involved. Priority: medium. Timeline: continuous.

(B) Forecasting future net emissions

-- Current Administration efforts:

- Use of economic models to generate scenarios of future emissions. EPA, DOE, and NSF are conducting such work, using a variety of economic models. U.S. agency work was reviewed and reported in the IPCC WGI/WGIII emissions scenarios.

-- Future work:

- Current economic models tend to focus on CO₂, separate sectors, and industrialized nations. Need to make use of new and expanded models that overhaul and elaborate current economic models to cover multiple RATGs, multiple sectors, and other important improvements. Ensure that these models include GHG sinks and other aspects of the comprehensive approach. DOE has a three-year phased project underway to accomplish this; EPA is working on improving its models. Priority: high. Timeline: 18 months to 5 years.

⁹For example, measurement of CH₄ emissions based on a proxy such as total acreage of rice cultivation might imply that the only option to reduce emissions is reduced rice cultivation, whereas changed practices using existing or new rice strains might accomplish the same at lower socioeconomic cost. In general, the use of proxies should not be allowed to conceal opportunities for changing the emissions factors or other assumptions from which the proxies derive.

(C) Monitoring net emissions in the future

This task is useful to test empirically the effects on RATG net emissions of observed changes in economic activity, economic structure, and technologies and practices. It is also useful to evaluate accomplishment of nations' espoused policies and of any limitation agreements reached in international accords.

-- Current Administration efforts:

- Efforts to improve monitoring of non-point emissions, including CH₄ emissions from rice cultivation (EPA) and ruminant animal husbandry (EPA); and GHG emissions from biomass burning (deforestation) (EPA, NASA, USDA).
- Efforts to improve monitoring of CH₄ emissions from energy systems such as natural gas transmission and fossil fuels extraction (DOE, EPA).

-- Future work:

- Use proxies/surrogates, developed for measurement of net emissions (section (A) above), to monitor emissions through monitoring of inputs, technologies and practices. Priority: high. Timeline: 18 months.
- Expand monitoring capacity and data to cover all relevant gases, sources, and sinks: data are especially needed on non-point sources of CH₄ and N₂O, e.g. agriculture, livestock; hydroxyl chemistry and atmospheric chemical reactions yielding tropospheric O₃; non-point sources and sinks of CO₂, including oceanic biota, terrestrial biota, long-term sequestration, plant lifecycles, grasses, soils, and trees, extent and effects of deforestation, and sink behavior. Priority: high. Timeline: 18 months to 5 years.
- Expand monitoring capacity and data to cover all nations. Current data generally cover industrialized nations. Develop an international network of cooperative net emissions monitoring. Priority: high. Timeline: 18 months to 5 years, depending on gas and sources/sinks.
- Harmonize techniques and data among nations and analysts. For example, resolve differences among nations monitoring deforestation (Brazil is urging that only its satellites produce reliable estimates of Brazilian land use). Priority: high. Timeline: 18 months to 5 years.
- Develop monitoring technologies and capabilities, as described under "(A) Measuring net GHG emissions" (above). Priority: medium. Timeline: 18 months to 5 years.
- Identify potential international and national methods for monitoring net GHG emissions; assess institutional,

political, social, and economic constraints on such monitoring, and means to overcome such constraints.

Priority: high. Timeline: 3 to 18 months.

- Assess options for monitoring arrangements, including arrangements for monitoring and reporting and their relation to sovereignty concerns, e.g. voluntary or mandatory national reporting; "national technical means" of observation of other nations' activities; remote sensing; atmospheric observations; international oversight bodies (e.g. UNEP investigators); permission for on-site inspections; bilateral trade partner review under emissions trading; incentives and institutional designs to encourage development and application of accurate monitoring & reporting, for example by assuring credit for net GHG limitation actions (e.g. climate-relevant actions justified on other grounds) upon a showing by the emitter of successful monitoring practices (see section VI below); verification and enforcement procedures and their rules, reporting and enforcement procedures, burdens of proof, forum (international or bilateral, political or scientific adjudicators, etc.). Examine role of nongovernmental organizations and public. Priority: high. Timeline: 18 months.

IV. Evaluating current national policies and proposals

Whether or not international agreement is reached on response strategies to potential climate change, nations are already announcing their intention to restrict emissions of one or more RATGs or to expand RATG sinks. The U.S. policy of pursuing climate-relevant measures justified on other grounds has been articulated in qualitative form; at some point the U.S. -- or others -- may choose to present quantifications of the net RATG effects of these U.S. measures. The comprehensive approach provides the basis for computing the aggregate impact of such diverse measures. In addition, it may be valuable for the U.S. to assess the policy claims and policy proposals being made by other nations, using the comprehensive approach, and to examine the policy opportunities that would face other nations under a comprehensive approach.

- (A) Extent and costs of net GHG limitations achieved by U.S. policy options within a comprehensive framework.

As described in the Introduction, it is useful to identify actions taken for other (non-climate) reasons but which influence net RATG emissions. One may calculate the percent limitations or reductions achieved by these policy actions using the comprehensive approach, and also calculate the marginal, average, and total cost per policy action.

This could be a first step toward assessing the marginal and total costs of RATG avoidance from different gas/source/sink policy options and hence toward assessing the relative cost-effectiveness of the comprehensive versus piecemeal approaches.

-- Current Administration efforts:

- analysis of US policies in EPA Cost Study/"Comprehensive Budget" analysis (covering U.S. energy efficiency and clean energy initiatives, CFC phaseout, afforestation, landfill rules, and other policies) through 2000. Priority: high. Timeline: 3 months.
- DOE/NES analysis of US energy policies through 2030, including NES options, afforestation, and CFCs. Priority: high. Timeline: 3 months.
- DOC study of future emissions under different tax options and under EC-wide strategy or global strategy. Priority: high. Timeline: 3 months.

-- Future work:

- Improve basis for projecting emissions limitations achieved by current policies
- Expand to cover influence of changes in agricultural subsidies, other relevant policy measures
- Look beyond 2000.

(B) Analysis of net GHG limitations achieved by other nations' policies

Analysis similar to that described for U.S. "no regrets" measures above should be undertaken for the policies announced and implemented by, proposed by, or available to, foreign nations. Certain nations have suggested unilateral limits on CO2 emissions (e.g. Sweden, possibly Japan), on nuclear power (Sweden, GDR), on SO2, NOx, and NMHCs (U.S.); and others have announced willingness to enact CO2 limits if others do too (e.g. U.K., Netherlands), and others have endorsed the Noordwijk Declaration's suggestion of CO2 emissions stabilization by industrialized countries by 2000.

-- Current work:

- Obtain information on each nation's policies.

-- Future work:

- Using a comprehensive approach, calculate the value of current policies in place in nations abroad, as

described above for U.S. actions.¹⁰ Assess how other nations would fare under a comprehensive approach.

Priority: high. Timeline: 3 months.

- Include consideration of foreign nations' agricultural subsidies and other relevant policies regarding non-point sources. Priority: high.

Timeline: 3 months.

- Expand to cover developing nations. Priority: high.

Timeline: 3 months.

- Using a comprehensive approach, calculate the influence each foreign proposal would have on net RATG emissions and GHG concentrations. Priority: high.

Timeline: 3 months.

- Include modeling of international energy markets and effect of price responses to unilateral demand reductions. Priority: high. Timeline: 3 to 18 months.

V. Evaluating the comparative cost-effectiveness of piecemeal, partial, and comprehensive approaches.

Advocacy of the comprehensive approach is based in part on the intuitively strong hypothesis that the marginal costs of control vary across gases, sources, sinks, and nations, so that for any assumed limitation obligation,¹¹ each nation's least-cost mix of limitation strategies would be different and all nations, regardless of their current RATG inventories, would be better off under a comprehensive approach than under an approach which placed separate limitation obligations on each gas or sector.¹²

¹⁰Special attention may be due the range of CFC-substitutes to be used by each nation. Japan, for example, is apparently presenting figures that show larger reductions in radiative forcing from phasing out unit amounts of CFCs than is the U.S., suggesting that Japan may be counting on selecting CFC-substitutes with lower GWPs than those to be used in the U.S. This also suggests that the Montreal Protocol, although potentially helpful as a no regrets measure, may not by itself be sufficient to address climate concerns associated with ozone-depleting substances.

¹¹As stated in the Introduction, given an assumed objective, the task is to assess the comparative costs of achieving it under different policy designs. This task does not assess the overall rationality or economic efficiency of the chosen objective.

¹²The aggregate shares calculated in the inventories (in Part III(B), above) do not indicate the costs of incremental limitations for each nation. Simply because a nation currently has a large share in methane, for example, does not mean that that nation would find methane reductions costlier than CO₂ reductions, at the margin. Economic analysis is needed to test the hypothesis of varying costs and to demonstrate the benefits to every nation of being afforded the cross-gas, cross-sector, and source-sink flexibility of the comprehensive approach.

This task is needed to test that hypothesis and, if confirmed, to demonstrate the value of the comprehensive approach.

- (A) Marginal costs: information and analyses needed to map full comparative cost-effectiveness functions and variations by gas, source, sink, sector, nation.

This task moves beyond analyses of specific existing policy programs and evaluates the full marginal cost functions facing policy makers and private actors.

-- Current Administration efforts:

- DOE/NES analysis for US energy sector policies and afforestation

-- Future work:

- Expand to cover all relevant gases, sources, sinks, sectors. Priority: high. Timeline: 3 months.
- Expand to cover other nations. Priority: high. Timeline: 3 months.
- Assess full social costs, using general equilibrium model rather than expenditures by the regulated industry.¹³ Make use of forthcoming models. Analyze costs over time, relation to innovation.¹⁴ Priority: high. Timeline: 18 months.
- Include (qualitative) evaluation of non-economic costs to response options, e.g. cultural or institutional barriers to certain policies. Priority: medium. Timeline: 18 months.
- Assess informational, administrative, and other transactions costs of piecemeal, partial and comprehensive approaches. Priority: medium. Timeline: 18 months.
- Evaluate the benefits (effectiveness) of policies, in terms of RATGs avoided. Priority: high. Timeline: 3 to 18 months.

- (B) Use cost-effectiveness analyses to evaluate costs and benefits to the US and other nations of possible

¹³ The comparative impacts on macroeconomic and international variables (e.g. trade, competitiveness, economic growth) would require separate study.

¹⁴ Evaluation should also address the likely economic impacts in the US and worldwide of potential future changes in the understanding of the gas-comparison index, and means to cushion adverse impacts (e.g. periodic public science reviews).

piecemeal, partial and comprehensive options that will be suggested for international policy design

This task moves beyond the analysis of current policy proposals suggested in section IV above to examine the marginal costs of policy designs, and to consider both proposed and hypothetical policy designs. It also focuses on international accords rather than national actions. This task is essential if U.S. policy makers and negotiators are to be able to assess policy proposals that inevitably be made as negotiations on a framework convention on climate change unfold.

Potential policy designs to be compared include: CO2 only, all RATGs, or all RATGs except those covered under the Montreal Protocol; sources only, point sources only, all sources and sinks, or sources and terrestrial sinks only; all sectors, or certain sectors (e.g. energy, industry, transport, agriculture, forestry).

Priority: high. Timeline: 3 to 18 months.

- (C) Evaluate the environmental effectiveness of comprehensive and piecemeal approaches: propensity and impact of induced shifts in residuals

Thus far, for any given policy goal, a piecemeal (e.g. CO2-only) approach and a comprehensive approach have been assumed to yield identical results in terms of aggregated GWP (or full environmental impacts). In other words, whether a reduction in net index-weighted ("CO2-equivalent") emissions were achieved in CO2 or in a combination of gases, the overall calculated effect on the index value of concern would be the same.

But such analysis fails to account for actual economic and social responses to policy interventions. Advocacy of the comprehensive approach is based in part on the intuitively strong hypothesis that including all gases, sources and sinks ensures better effectiveness in any effort to limit contributions to potential radiative forcing (or full impacts), because piecemeal rules applying to one gas, source (or sector), or sink will engender shifts of socioeconomic activity from regulated to unregulated modes, undercutting achievement of policy goals. Case studies will be especially helpful to illustrate these issues.

-- Current Administration efforts:

- Understanding of prior piecemeal approaches in environmental regulation and their resultant shifts of residuals, including single-medium approaches, e.g. to

discharges into air, land, and water; and single-pollutant approaches, e.g. to SO₂.

- DOE/NES study will address CO₂ and CH₄ emissions from energy sector; it should consider potential GHG-related environmental effects of fuel switching, new energy sources, and sectoral shifts.

-- Future work:

- Develop "crisp retorts" to piecemeal approaches: Conduct case studies of cross-gas shifts: e.g. fossil fuel switching (coal to natural gas) induced by CO₂-only policies could have attendant impacts on CO₂-to-CH₄ emissions shifts due to CH₄ leakage from natural gas transport.¹⁵ Expand cross-gas shift studies, e.g. apply coal-to-gas CO₂-CH₄ shift analysis to actual global GHG output and in light of likely GHG emissions/leaks from future coal and gas facilities. Priority: high. Timeline: 3 months.

- Evaluate cross-source/sector shifts: e.g. under a transport-only policy (such as a high CAFE statute), possible shift from fossil fuel combustion on board vehicles to electric cars powered by central utility combustion, or to use of intensely cultivated biomass fuels; e.g. under an energy-only or fossil fuel-only policy, possible shift to biomass fuels whose cultivation emits other GHGs. Priority: high. Timeline: 3 months.

- Include consideration of international market responses to unilateral policy choices. Assess cross-boundary shifts, through price effects and industry flight, of unilateral or OECD-only policies. Priority: high. Timeline: 3 months.

(D) Evaluate the environmental benefits of a "net emissions" approach

A net emissions approach, encompassing both sources and sinks, would encourage sink protection and expansion, whereas a source-only approach would not. Sink policies encouraged could include afforestation and protection of marine phytoplankton from pollution. This task is to evaluate the side benefits of likely sink policies, e.g.

¹⁵ See, e.g., Rodhe, Science 8 June 1990. Using a 100-year time horizon and a CO₂-equivalent GWP for CH₄ of 10, Rodhe estimates that if a CO₂-reduction policy were accomplished by fuel switching from coal to natural gas, a 3-6% CH₄ leakage rate from natural gas transport facilities would fully offset all the CO₂ reductions resulting from the fuel switch.

reduced soil erosion, enhanced biodiversity, protected phytoplankton, and better timber management.

VI. Bridging from piecemeal to comprehensive approaches

(A) Addressing the objection that the comprehensive approach is technically difficult or infeasible

As discussed in the introduction, the comprehensive approach can be applied to assist in design of various policies, including research strategies, technology development strategies, enumeration of steps justified on other grounds, and emissions limitation strategies. For most of these options, the comprehensive approach can be applied immediately, despite potential uncertainties, as a general guide to intelligent analysis of the scope and relative importance of policy choices.

For implementing emissions limitations, however, prompt application of the comprehensive approach might be somewhat more difficult. In principle, a comprehensive approach appears to be the most appropriate way to design any emissions limitation policy. But as indicated above, there are noteworthy gaps and uncertainties in the information on emissions of certain gases from certain sources and uptake by certain sinks. If emissions limitations were to be imposed today, a fully comprehensive approach would not be available. If emissions limitations are not needed immediately, work on the comprehensive approach can continue toward a time when limitations might be agreed. If emissions limitations are to be agreed at some point before all informational gaps are filled, a partially comprehensive approach could be employed with a mechanism for moving to a fully comprehensive approach as these gaps are filled.¹⁶

The issue for policy makers is not whether the comprehensive approach is "feasible," but whether at any point the social costs of implementing an incompletely comprehensive approach -- in terms of environmental effectiveness and economic efficiency, as described in section V above -- are outweighed by the social costs of obtaining additional information (including costs of delay). Such costs would also include transactions costs and administrative costs. In other words, one must ask whether the marginal value of additional information (leading to a more comprehensive approach) exceeds the marginal cost of obtaining additional information. Another way of examining the issue is to

¹⁶Yet it must be recognized that piecemeal approaches, once adopted, generally attract vested interests who resist any efforts to expand toward a comprehensive approach.

ask at what point would one know enough to proceed comprehensively; and to ask how (and at what cost) a comprehensive approach could evolve from incremental steps. Further, one would consider institutional means to incorporate incentives into any partial strategy that encourage evolution toward a comprehensive approach.

The scientific building blocks of the comprehensive approach are described above in sections I-III. Any framework convention should foster scientific research through a comprehensive approach. In addition, consideration of the need to bridge from a partial to a comprehensive approach would include:

-- Future work:

- Assess the time and expense needed to answer scientific questions, develop proxy measurement devices, and build monitoring capabilities to achieve a workable comprehensive approach.
- Assess other constraints to employment of a fully comprehensive approach, including institutional, political, cultural and economic obstacles.
- Compare the costs of acquiring this needed information to the socioeconomic and environmental costs (and foregone benefits) of adopting a piecemeal policy design for want of such information.
- Develop policy and institutional designs that offer incentives for needed research. For example, an emissions limitation obligation in an international agreement could be framed in a piecemeal fashion but offer the opportunity to emitters to achieve compliance through limitation actions addressing other GHGs, sources or sinks, so long as the emitter demonstrates the accomplishment. This would give emitters incentives to undertake the research needed to develop new monitoring capabilities.
- Consider intermediate approaches such as incremental or phased-in designs toward comprehensivity, and means to bridge from them to a fully comprehensive approach.

Overview: Priority: high. Timeline: 3 to 18 months.

(B) Integrating prior and concurrent law and policies into a comprehensive approach.

Even if a fully comprehensive approach were available for use in emissions limitations at any relevant point, it is apparent that other treaties, laws and policies will already be addressing discrete RATGs, sources, and sinks. Some means would be needed to accommodate and integrate these diverse endeavors into the comprehensive approach. Several options are available for such integration. One option is to use a comprehensive approach to net RATGs in any emissions limitation protocol while varying the baseline of allowed credit according to prior treaty obligations. Another option is to have the convention mandate that any future protocol (if any) employ a comprehensive approach. A related option is to incorporate in a framework convention on climate the assurance to nations, in advance of any hypothetical future protocol obligations (not yet agreed to), that they would receive credit against any such obligations for current or past (after a certain date) net emissions limitations actions, whether taken pursuant to treaties or national policies; the convention would further calculate the value of such actions according to the comprehensive approach. This would assure credit for measures justified on other grounds, avoid disincentives to those actions, and give root to the comprehensive approach, while not yet committing to emissions limitations obligations.

-- Current Administration efforts:

- devising means to ensure that international agreement integrates (gives credit for) current actions, other international agreements (forestry, VOCs, GHGs covered by ozone agreements), other domestic laws and initiatives. (DOJ, EPA, State)

-- Future work:

- Demonstrate incentive advantages of integration
 - lack of integration would yield perverse disincentives to take actions, even actions that are justified on other grounds, lest they be denied credit once emissions limitations are agreed. Priority: high. Timeline: 3 months.
- Address possible overclaiming (see "monitoring" and "verification," above). Priority: medium. Timeline: 18 months.
- Analyze advantages for other nations under integrated design. Priority: high. Timeline: 3 months.
- Analyze environmental advantages of integration. Priority: medium. Timeline: 3 months.
- Address issues of legal grafting presented by terms or design of other agreements, laws. Priority: high. Timeline: 3 months.

- Consider possible offset model (e.g. defining any limitation obligations in terms of CO2 emissions, to satisfy those eager for CO2 limits, but authorize offsets for any verifiable limits on any GHG, source, or sink, thus effectively constructing a comprehensive approach). Priority: medium. Timeline: 3 to 18 months.

Research and Analysis Underlying the Incentives Approach

As described in the Introduction, a variety of market-based incentives might be considered in the climate change context. The possible uses and advantages of these approaches are summarized in the Introduction.

I. Emissions trading

(A) Domestic trading

- Current Administration efforts:
 - review of past and current experience, e.g. lead phasedown, netting/bubble/offset program, CFCs trading, new acid precipitation trading scheme. Primarily EPA, DOE, CEA.
 - consider application to GHGs; consider issues of implementation, e.g. informal versus formal trading; who would trade; duration of allowances; means of distributing allowances; market power; hoarding; scope of GHGs, sectors, sources and sinks; monitoring trades; etc.
- Future work:
 - Evaluate the comparative cost-effectiveness of emissions trading and command-and-control approaches. Priority: high. Timeline: 3 to 18 months.

(B) International trading

- Current Administration efforts:
 - present US experience and suggestions at international discussion on application to climate
- Future work:
 - Extend analysis of above issues to international context, e.g. informal versus formal trading; who

would trade; duration of allowances; means of distributing allowances; market power; hoarding; scope of trading among GHGs, sources, sinks, sectors, industries, geographical areas, stages of development; monitoring trades. Priority: medium. Timeline: 3 to 18 months.

- In addition, consider international institutions; trade, assistance and national income implications; sovereignty issues; cultural or ethical objections to so-called "selling the right to pollute"; trading as a decentralized, market-based vehicle for resource and technology transfers.¹⁷ Priority: medium. Timeline: 3 to 18 months.

- Assess informational, administrative, and other transactions costs of emissions trading and command and control policies. Priority: medium. Timeline: 3 to 18 months.

- Identify opportunities for cross-national trades, and hence likely trading partners (for the US and worldwide). Priority: high. Timeline: 3 months.

- Evaluate the comparative cost-effectiveness of emissions trading and command-and-control approaches. Priority: medium. Timeline: 3 months.

II. Emissions fees

Fees might be employed domestically or internationally to address GHG emissions. Options discussed to date include carbon taxes based on the carbon content of energy fuels, and energy taxes. Other options include an energy sector tax that covers both CO₂ and CH₄ emissions from energy activities, using their GWP index ratings to weight the tax; and a more general multi-sector tax calibrated to the GWP index (or full environmental impacts index) rating of each gas.

-- Current Administration efforts:

- analysis of energy sector taxes in DOE/NES
- analysis of various fees in EPA "Comprehensive Budget" analysis
- related efforts: numerous studies have used assumed taxes to examine costs of GHG limitations policies. E.g. CBO (Montgomery), Manne & Richels, Nordhaus. See CEA overview of Economics of Global Change.

¹⁷ In addition, consider the options for trading within regional associations such as OECD, EC, ASEAN. Evidently the EC and OECD are both considering association-wide policies.

-- Future work:

- Improve assessment of tax implications. Consider international fuels market impacts; use general equilibrium models; address fiscal concerns. Priority: high. Timeline: 3 months.
- Consider variety of tax policy designs, including, carbon, energy, GWP within energy sector, etc. Priority: high. Timeline: 3 months.
- Much of this kind of consideration must be deferred to budget negotiations.

III. Adaptation Incentives

Market mechanisms and institutional reforms could be used to encourage efficient adaptation practices. Because of current institutional or market failures, long-range investments, such as coastal construction or water use planning, might be undertaken without giving appropriate weight to any climate change risks (e.g. rising sea levels or shifting precipitation). Such institutional or market failures might be addressed by informational or incentive-based policies, such as requiring coastal construction to purchase subsidence insurance, or encouraging long-range water use planning to take account of potential precipitation patterns. Some of these types of policies were addressed in the IPCC/RSWG RUMS and CZMS reports.

IV. Economic instruments in general

-- Future work:

- Pursue contacts with OECD regarding Environment Ministerial in January, Economic Instruments analytic workplan (experts meeting now tentatively slated for October 1990), and potential OECD Workshop on Economic Instruments.¹⁸ Priority: high. Timeline: 3 to 18 months.
- Develop suggestions for economic analysis and study of economic instruments in upcoming IPCC Future Workplan discussions (tentatively slated for December or January). Priority: high. Timeline: 3 to 18 months.

¹⁸ Preparing for the suggested OECD Workshop on Economic Instruments, tentatively slated for December 1990, will involve considerations of forum and cosponsorship, logistics and timing, relation to other OECD meetings, relation to other international meetings, invitees, topics to address, an October experts meeting, relation to the upcoming IPCC meeting on Future Work of the IPCC, and US presentation(s) at the December Workshop.

- Continue to work with CEES groups, including the new Ad Hoc Economics task group, to develop economic analysis of policy proposals and designs (addressing "comprehensive approach" issues as well as "incentives" approach issues). Priority: high. Timeline: 3 months to 5 years.

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Proposed Agenda

First Negotiating Session

Framework Convention on Climate Change

Washington, D.C.

February 4 - 14, 1991

Sunday, February 3

1600 Registration - until 2000

Monday, February 4

0800 Registration

1000 Welcome by Host Government Representative

1015 Remarks of Host Government Representative

1025 Remarks of WMO Secretary General Obasi

1045 Remarks of UNEP Executive Director Tolba

1125 Remarks of IPCC Chairman Bolin

1145 **BREAK**

1200 Election of Chair

1215 Adoption of Rules of Procedure

1300 **LUNCH**

1500 Appointment of Credentials Committee

1515 Adoption of Agenda

1530 Election of Bureau/Organization of Work

1830 Buses Depart for Reception

1900 USG Reception

2100 Buses Depart for Hotels

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- 2 -

Tuesday, Feb. 5

1000 Delegation Statements (max. 5 min. each)
1300 LUNCH
1500 Delegation Statements (max. 5 min. each)
1800 ADJOURN

Wednesday, Feb. 6

1000 Delegation Statements (max. 5 min. each)
1300 LUNCH
1500 Preparation of Legal Negotiating Text
1800 ADJOURN

Thursday, Feb. 7

1000 Preparation of Legal Negotiating Text
1300 LUNCH
1500 Preparation of Legal Negotiating Text

Friday, Feb. 8

1000 Preparation of Legal Negotiating Text
1300 LUNCH
1500 Preparation of Legal Negotiating Text
1800 ADJOURN

Saturday, Feb. 9 (Optional)

1000 Preparation of Legal Negotiating Text
1300 ADJOURN

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- 3 -

Monday, Feb. 11

1000 Preparation of Legal Negotiating Text
1300 LUNCH
1500 Preparation of Legal Negotiating Text
1800 ADJOURN

Tuesday, Feb. 12

1000 Preparation of Legal Negotiating Text
1300 LUNCH
1500 Simultaneous Meetings of Legal Drafting Group and
Plenary to Discuss Future Work
2000 Legal Drafting Group
2300 ADJOURN

Wednesday, Feb. 13

1000 Report of Credentials Committee
1015 Future Work (continued)
1200 Consideration of Draft Report
1300 LUNCH
1500 Review of Draft Legal Text
1800 ADJOURN
(Night Session Possibility)

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- 4 -

Thursday, Feb. 14

1000 Review of Draft Legal Text
1300 LUNCH
1430 Adoption of Final Report
1500 ADJOURN

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Intergovernmental Negotiating Committee
for Framework Convention on Climate Change - First Session
Washington, D.C. USA 4-14 February 1991

1. The meeting will take place at the Westfields International Conference Center, 14750 Conference Center Drive, Westfields, Virginia 22021, USA

Telephone: (703) 818-0300

Fax: (703) 818-3655

Pre-session documentation is being sent under separate cover.

2. Registration will take place at the Westfields Conference Center on Sunday, 3 February, from 1600 to 2000 and on Monday, 4 February, from 0800 to 1800. Delegates are urged to register on Sunday, if possible.
3. The U.S. Government will host a welcome reception from 1800 to 1930 on Sunday, 3 February 1991.
4. The session will begin promptly at 1000 on Monday, 4 February. Delegates are asked to be seated in the plenary hall by no later than 0945.
5. A special package rate for 3-14 February (inclusive) has been arranged through the Westfield's International Conference Center, where the negotiations will take place. The accomodations package is based on a special rate of \$130 per day (or part thereof), and includes room, all meals and access to extensive recreation facilities. On site hotel accomodations (310 rooms) are available at the Center and can be reserved on a first come, first served basis. Priority will be given to national delegations through 7 January. When the Conference Center is filled, Westfields will book accomodations as needed at a nearby corresponding hotel, which will have shuttle service to the Center.
6. Participants will be responsible for making their own lodging arrangements through the Westfields International Conference Center. National delegations may find it convenient to do so through their country's mission in Washington or New York.

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7. Participants are advised that there is no public transportation between the Conference Center and central Washington. Taxis and rental cars are expensive (taxi fare one way is approximately \$35.00) and time consuming, especially during rush hours. Delegates are strongly advised to make use of the especially advantageous arrangements made for the conference, as in paragraph 5 above.
8. Accompanying persons staying in the Conference hotels will pay the normal hotel rates.
9. Reservations from national delegations received by the Westfields International Conference Center before Monday, 7 January 1991, will receive priority treatment. (Please use Annex I - the combined hotel reservation and pre-registration form.)
10. WMO and UNEP will aim to ensure that applicants for funding, from developing countries, (on the basis of one delegate per country proposed by the country's Ministry of Foreign Affairs), will have travel and financial arrangements completed by the UNDP office in their country before departure, provided applications are received in Geneva or Nairobi before Monday, 7 January 1991. (Please apply using the form at Annex II.)
11. Participants are advised that the most convenient international arrival point in Washington is Dulles International Airport, located about 11 kilometers (approximately 15 minutes) from the Conference Center. A shuttle bus service between Dulles and the Conference Center can be arranged for approximately \$9.00 per person to meet national delegates and agreed observers arriving at Dulles. Those who wish to use this service should notify the Westfields International Conference Center - Conference Director (FCCC) - of their flight number and expected arrival time at least 48 hours in advance. (See telephone and fax numbers in paragraph 1 above.)

Taxis are also available between Dulles Airport and the Conference Center. Taxis run on a meter basis; the cost is approximately \$12-13.00 one way.

Bus service is available between Washington National Airport and Dulles International Airport. Washington Flyer buses leave National Airport seven days a week every hour on the hour between 0600 and 2200. The cost is \$12.00 one way or \$22.00 round trip. Travel time between National Airport and Dulles Airport is approximately 45 minutes. Tickets may be purchased at Washington National Airport at the Washington Flyer Information Desk located outside the main terminal near United Airlines.

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-3-

12. Participants are advised that hotels in the United States normally require guests to present a major credit card on registration or to pay in advance.

13. Mail for participants may be addressed to:

Dr./Mrs./Miss/Mr. _____
c/o Conference Director (FCCC),
Westfields International Conference Center,
14750 Conference Center Drive,
Westfields, Virginia 22021, USA

14. Banking and currency exchange facilities will be available at the Conference Center.

15. An airline and car rental desk will be available at the Conference Center for participants' use. A variety of tourist activities will be available on Saturday, 9 February, and Sunday, 10 February. Participants should make their bookings at the Conference Center's travel service support desk.

16. Participants are advised that the United States requires visas for visitors from most countries. Those not holding valid visas are encouraged to make application to the appropriate U.S. consulate as soon as possible.

17. The following climate information for Washington in February has kindly been provided by the US National Weather Service:

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First Negotiating Session on a Framework Convention on Climate Change, Washington, February, 1991

HOTEL RESERVATION AND PRE-REGISTRATION FOR THE MEETING

1. Please reserve me a room at one of the Conference Hotels.
2. I expect to arrive on _____ (day/month) and to depart on _____ (day/month).
3. I understand that the cost for full board will be US \$130 for each 24 hour period or part thereof and that I shall be responsible for payment to the hotel.
4. Country/organization: _____
Family name: _____
Other names: _____
Official title: _____
____ Head of Delegation
____ Alternate
____ Adviser
____ Observer
5. Official address: _____

6. Office telephone: _____
7. Telex number: _____
8. Fax number: _____

Signed _____ Date _____

When completed, please return this form to:

Westfields International Conference Center
14750 Conference Center Drive
Westfields, Virginia 22021, USA
Telephone: (703) 818-0300
Fax: (703) 818-3655

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A COMPREHENSIVE APPROACH TO CLIMATE CHANGE

Briefing to the DPC Global Change Strategy Group

Presentation by the Department of Justice,
Environment & Natural Resources Division

November 28, 1990

- OFFICIAL USE ONLY -

"Comprehensive Approach" described

- o An approach or heuristic to guide consideration of climate change issues.
- o Considers all anthropogenic inputs: net emissions (sources less sinks) of relevant trace gases, weighted by the environmental impacts of each gas.
- o Considers the several trace gases of interest:
 - Carbon dioxide (CO₂)
 - Methane (CH₄)
 - Nitrous oxide (N₂O)
 - Chlorofluorocarbons (CFCs)
 - Hydrochlorofluorocarbons (HCFCs)
 - Tropospheric Ozone (O₃) and its precursors:
 - Nitrogen oxides (NO_x)
 - Carbon monoxide (CO)
 - Volatile organic compounds (VOCs)
- o Considers sources and sinks of these trace gases in every sector of human activity:
 - Energy generation
 - Transportation
 - Agriculture
 - Forestry and land clearing
 - Industry
- o Employs a measure, such as an index, of the comparative environmental impacts of the gases

Anthropogenic Sources & Sinks of Selected Gases

<u>Gas</u>	<u>Sources</u>	<u>Sinks</u>
Carbon dioxide (CO ₂)	Fossil fuel combustion Land clearing	Forests Grasses Soils Ocean biota & storage
Methane (CH ₄)	Enteric fermentation in livestock Rice cultivation Wetlands Landfills Natural gas drilling, venting, transmission Coal mining Biomass combustion	Atmospheric OH interaction Soil removal
Nitrous oxide (N ₂ O)	Agricultural fertilizers Land clearing	Soil removal
Halocarbons (CFCs and related)	Refrigerants Aerosol propellants Foam blowing agents Solvents and cleaning agents Fire retardants	
Tropospheric Ozone (O ₃)	Precursors: CH ₄ , CO, VOCs, in the presence of NO _x Transport of strat. O ₃ into troposphere	Halocarbon depletion
Carbon monoxide (CO)	Fossil fuel combustion Biomass combustion Precursors: CH ₄ , VOCs	Atmospheric OH interaction
Nitrogen Oxides (NO _x)	Fossil fuel combustion Biomass combustion Agriculture	
Volatile Organic Compounds (VOCs)	Fossil fuel combustion Biomass combustion Industry	Atmospheric OH interaction
Aerosols/sulfates (e.g. SO ₂)	Fossil fuel combustion	

Comparing trace gases

- o Need for a measure of relative impacts. A measure, or index, is needed to compare the environmental impacts of each trace gas. This measure ensures accounting for activities' overall impacts on the environment, while allowing decision makers the flexibility to fashion a mix of efforts directed at diverse gases.
- o Weighting can't be avoided. Any policy will employ some index to weight the gases, whether implicit or explicit. A CO2-only policy implicitly weights the other gases at zero.
- o GWP. One such measure is the "Global Warming Potential" (GWP) index, presented in the IPCC Report. The GWP measures the relative radiative forcing of each gas over time -- its potential to warm the atmosphere.

Gas	Instantaneous radiative forcing per kg	Atmospheric residence years (estimated)	Relative radiative forcing potential over years		
			20	100	500
CO2	1	120	1	1	1
CH4	58	10	63	21	9
N2O	206	150	270	290	190
CFC-11	3970	60	4500	3500	1500
CFC-12	5750	130	7100	7300	4500

(Source: IPCC Scientific Assessment, tables 2.3 and 2.8.)

- o Some uncertainties remain in the GWP values, relating principally to the residence times of gases such as CO2 and N2O. They do not warrant abandoning the index.
- o Time and discounting need further discussion.
- o Other comparative measures might also be developed. For example, a "global change index" could incorporate other salient global impacts of the gases in addition to their radiative forcing. These other global impacts include beneficial plant enrichment from CO2, and adverse stratospheric ozone depletion from CFCs and some of their substitutes. Ignoring these impacts could lead to perverse results, such as a limit on warming that induces other adverse environmental consequences. Yet a multiple attribute index would require a challenging analytic exercise, and its development should initially proceed as a complement not a rival to a radiative forcing index.

Comprehensive approach has multiple applications

- o Research. Designing research strategies to generate the most valuable information, by focusing attention on the climate variables of concern for which information is lacking.
- o Technology evaluation. Calculating the effects on net emissions of new technologies and practices. Possible uses in foreign technology assistance, federal R&D funding, assessments of technology choices encouraged by other regulatory programs.
- o Inventories. Calculating current net emissions of relevant trace gases, by nation and sector.
- o Report cards. Calculating the likely effects on net emissions of current policy actions.
- o Policy choices. Calculating the effects on net emissions of potential policy actions proposed by others or considered by the U.S.
- o Policy design. Defining any agreed response measures in terms of a comprehensive approach, accounting for and allowing flexibility among all relevant gases, sources and sinks.

"How to" and "how much"

- o In general, the comprehensive approach addresses "how to," that is, the design of cost-effective responses (including research, technology development, limitations, etc.). It does not directly address the question of "how much" response to potential climate change is desirable; that is the province of overall cost-benefit analysis, which considers the aggregate costs and benefits of change and of actions to respond.
- o The comprehensive approach does shed light on some approaches to the question of "how much," by ensuring attention to the arguably limited environmental benefits and high economic costs of piecemeal policy measures.

Advantages of a Comprehensive Approach to Policy Design

- A. The dominant tenor of climate policy discourse has been piecemeal, addressing each trace gas and each sector separately. Most policy proposals, and most data collection efforts, have focused on energy sector CO2 emissions.

- B. Comprehensive approach offers environmental advantages
 - o Piecemeal policies have proved environmentally ineffective or even counterproductive. The history of environmental policy has been piecemeal efforts aimed at air, water, and land emissions separately, leading to cross-media shifts in residuals.

 - o Administration efforts to employ better approaches:
 - multimedia approach to solid and hazardous emissions
 - multipollutant approach to air emissions
 - multimedia enforcement actions
 - comprehensive approach to climate context

- o Shifting residuals. Piecemeal approaches in the climate area could lead to counterproductive cross-gas tradeoffs. Narrow focus on one trace gas could induce shifts in emissions to unregulated gases and sectors.

Examples:

(1) Piecemeal policy aimed at CO₂ alone could induce fuel-switching from coal or oil to natural gas, with attendant reduced CO₂ emissions from combustion, but increased CH₄ output from transmission leakage.

Methane offset from fuel-switching to Natural Gas:

	Typical grams of CO ₂ emitted per MJ (in Sweden)	CH ₄ leakage rate that offsets 100% of CO ₂ savings
Coal	92	6%
Oil	78	4%
Nat. Gas	56	--

(Calculated from Rodhe, Science 8 June 1990, using Rodhe's GWP figure of CH₄ = 10 GWP per mole CO₂ over 100 year integration period.)

Current average Natural Gas transmission CH₄ leakage rates:

USA:	1%
Australia:	3%
USSR:	5-10% ?

(2) Piecemeal focus on limiting agricultural CH₄ could induce use of nitrogenous fertilizers that reduce CH₄ emissions per yield but raise N₂O emissions.

(3) Piecemeal focus on transport emissions might induce shifts to energy sector (e.g. if electric vehicles are powered by coal-fired boilers) or to agriculture sector (e.g. if biomass for alternative fuels is cultivated with nitrogen fertilizers).

- o Comprehensive approach ensures that such shifts are accounted for by decisionmakers.
- o Side benefits. By focusing on "net" emissions, the comprehensive approach fosters sink protection and expansion, such as afforestation and protection of phytoplankton. Benefits include biodiversity, reduced soil erosion, protected food webs.

C. Comprehensive approach offers economic and social advantages

- o Piecemeal approach is economically inefficient. Piecemeal policy would preclude alternatives that achieve the same environmental outcome at less cost. For example, a policy aimed only at energy sector CO₂ would bar less costly abatement options such as afforestation, CH₄ reductions, attention to CFC-substitutes, or N₂O reductions.
- o Flexibility reduces costs. The costs of different options will vary across nations, so to minimize costs each ought to have the flexibility to build its least-cost policy mix among the gases and sectors.
(Even if a multi-gas inventory would rank some nations higher in net emissions than they would under a single-gas accounting, all nations could gain as the marginal cost of abatement is reduced through greater flexibility.)
- o Burden sharing. A comprehensive approach provides a more "level playing field" across nations, in contrast to a piecemeal approach which effectively singles out nations with one pattern of economic and social activity. Offers the possibility of smoother, and more sober, international cooperation.

Potential objections to a comprehensive approach

- o Data and monitoring of sources and sinks are inadequate
 - Build better data and monitoring
 - Employ carefully chosen proxies or surrogates for difficult-to-measure emissions
 - Design incentives for monitoring improvements, such as offering emissions credit to those who demonstrate better monitoring techniques.
- o GWP Index is uncertain
 - Boulder workshop suggests fundamentals well accepted
 - Work toward improvements
 - Absolute precision may not be required initially; changes in index numbers could be made at wide intervals and/or prospectively
- o Other discrete actions will have already been taken, e.g. forestry agreement, CFCs, VOCs
 - Integration of prior and current actions into comprehensive approach will be necessary
- o CFCs should not be included in comprehensive basket
 - Comprehensive approach would not allow violation of the Montreal Protocol
 - CFCs are a major share of radiative forcing, and their elimination should be recognized
 - Some nations are doing more to reduce global CFCs than others, and their contribution should be recognized
 - Faster reductions, or reductions in other substances not controlled, or in other nations, could earn credit; this would provide helpful incentives in support of the Montreal Protocol
 - CFC substitutes may be quite important to radiative forcing

Research needed in the short term to support the comprehensive approach. The "Interim Report" of the Task Force on Comprehensive and Incentives Approaches identified tasks needed in the next three months, including:

(1) Index. Develop an improved radiative forcing index and outline a plan for further improvements. Incorporate new research results. Draft a proposal for a standing international expert group, to be established in the framework convention, that would develop the index further and would shepherd it toward accuracy, international consensus, and continuing reassessment in light of new research. Draft talking points on time horizons. Outline a global change index, incorporating salient environmental effects in addition to radiative forcing; provide a rough quantitative estimate of its measure.

(2) Emissions monitoring. Draft a proposal for international emissions monitoring network(s) to cover all gases, sources and sinks. Identify specific techniques to be used (e.g. satellites, ground stations). Highlight gaps in knowledge and disputes over methods. Develop proxies or surrogates where needed.

(3) Documenting environmental advantages of a comprehensive approach. Formulate "crisp retorts" or "zingers" to deflate piecemeal proposals, showing they would have little environmental benefit, or actually be counterproductive. Calculate effects of cross-nation, cross-gas, cross-sector shifts. Collect empirical examples of the environmental backfiring of piecemeal strategies applied to other environmental problems.

(4) Documenting economic advantages of a comprehensive approach. Develop quantitative estimates of the marginal cost of abatement of different gases in different selected nations.

(5) Report card. Update the comprehensive "report card" or "budget" of net index-weighted emissions changes achieved by climate-relevant actions taken for other reasons. Repeat analysis for selected foreign nations.

(6) Updated discussion papers on comprehensive and economic incentives approaches. Write updated and improved paper(s) explaining the comprehensive and incentives approaches, giving empirical examples, and discussing practical advantages and challenges to their use in the climate context. Develop plans for future seminars.

Options for Including a Comprehensive Approach in the Convention

- (1) Monitoring. Comprehensive source and sink monitoring: cooperative international networks addressing all relevant trace gases. Create institutions for data sharing, harmonizing methodologies, R&D on new techniques.
- (2) International inventories. Build the capacity to estimate international net emissions of relevant trace gases: baseline levels and changes due to policy actions. National reporting, workshops to compare numbers and methods.
- (3) Index. Cooperative development and refinement of an index. Create institutional expert body to conduct regular reassessments and keep policy makers informed of research developments.
- (4) Framing policy. Ensure that any limitations obligations (if any, whether now or in the future) are defined in terms of a comprehensive approach. This could be required, or at least endorsed, in the convention.
- (5) Advance assurance. Give advance assurance that current actions will receive "credit" against any future limitations obligations, in accordance with a comprehensive approach.

Pros: Helps avoid disincentives to taking actions justified on other grounds; nations may hold such actions in abeyance lest they lose credit for them. Provides an institutional means to integrate discrete initiatives (e.g. CFCs, forestry, VOCs, and any national actions such as CAA, tree planting, energy efficiency). Ensures that a comprehensive approach to such credit will be used.

Cons: Requires debate over baseline.
- (6) Technology evaluation. Employ a comprehensive approach to assess any technology transfer activities.

Options for Laying the Basis for International Trading in the Convention

- (a) REIOs. Broaden the notion of "regional economic integration organization" (REIO) to allow any group of nations to work together. The term REIO is employed in the Montreal Protocol to allow regional groups like the EC to form a group-wide CFC emissions bubble. It could be broadened to allow joint undertakings by less formalized groups of states, and by non-contiguous states.
- (b) Joint cooperation. Include language acknowledging that any obligations can be met through "joint cooperative arrangements." Applies to technology development, emissions limitations, other obligations.
- (c) Registry. Develop an international information center on trades. The center could initially gather information and provide advice on how to arrange and implement effective trades. It could start with information on, e.g., debt-for-nature swaps and EC bubble activities. It could grow to become a trading registry if full-scale international trading developed.
- (d) Financial and technology transfers. Incorporate emissions credits into international technology transfer and financial assistance arrangements. Funds and technology transferred by donor countries, directly or through a global environmental funding facility, could earn credits for the donors corresponding to the net emissions change (calculated in terms of a comprehensive approach) achieved by the transfer. The donor could then submit the credit in compliance with any international limits on emissions that might later be agreed.

1985 EMISSION TOTALS BY GAS
(IN TERAGRAMS; ON A CO2-EQUIVALENT BASIS USING IPCC GWP'S FOR 100-YEAR TIME HORIZON)

	CO2	CH4	N2O	CO	CFC-11	CFC-12	HCFC-22	CFC-113	CH3CCl3	CCL4	HALON-1301	CFC-114	CFC-115	EMISSIONS	%
UNITED STATES	4588	741	518	567	168.7	775.3	95.1	241.1	39.4	30.2	5.2	35.9	16.6	7822.0	18.7%
USSR	3490	722	168	132	78.6	346.8	4.2	25.7	5.8	12.2	0.8	9.2	2.3	4997.4	11.9%
CHINA	2168	1028	160	67	7.1	42.1	0.4	2.9	0.7	1.4	0.0	1.2	0.4	3478.8	8.3%
BRAZIL	1394	482	155	32	13.8	27.0	0.5	2.9	0.7	1.3	0.1	1.0	0.2	110.4	5.0%
INDIA	495	1011	56	28	5.1	30.2	0.3	2.1	0.5	1.0	0.0	0.9	0.3	1630.9	3.9%
JAPAN	894	97	28	52	72.5	197.2	15.1	137.4	4.1	8.2	0.5	6.4	1.7	1515.4	3.6%
INDONESIA	789	295	93	13	17.3	33.6	0.6	3.7	0.8	1.6	0.2	1.3	0.3	1249.6	3.0%
FEDERAL REP. GERMANY	754	119	28	47	68.2	100.6	3.2	25.3	2.9	5.6	0.4	4.6	1.0	1160.9	2.8%
UNITED KINGDOM	545	91	25	38	63.2	93.3	3.0	23.4	2.7	5.2	0.4	4.3	1.0	894.3	2.1%
THAILAND	394	227	44	5	5.4	10.5	0.2	3.1	0.7	0.5	0.0	0.4	0.1	688.9	1.6%
CANADA	469	81	25	50	10.6	37.9	0.5	3.1	0.7	1.5	0.2	1.2	0.2	680.5	1.6%
FRANCE	347	81	24	34	61.5	90.8	2.9	22.8	2.6	5.1	0.4	4.1	0.9	677.7	1.6%
POLAND	432	123	18	6	10.6	46.7	0.6	3.5	0.8	1.6	0.1	1.2	0.3	643.7	1.5%
ITALY	345	41	16	23	63.8	94.2	2.0	23.7	2.7	5.3	0.4	4.3	1.0	619.8	1.5%
AUSTRALIA	381	114	19	22	9.5	25.8	0.3	18.0	0.5	1.1	0.1	0.8	0.2	558.4	1.3%
MEXICO	335	88	29	29	8.6	16.9	0.3	1.8	0.4	0.8	0.1	0.7	0.2	556.5	1.3%
SOUTH AFRICA	240	68	9	9	3.4	6.6	0.1	0.7	0.2	0.3	0.0	0.3	0.1	433.5	1.0%
PHILIPPINES	146	101	27	4	5.7	11.2	0.2	1.2	0.3	0.5	0.1	0.4	0.3	391.2	0.9%
NETHERLANDS	161	35	6	7	16.3	24.1	0.8	6.0	0.7	1.3	0.0	1.1	0.1	252.0	0.6%
SOUTH KOREA	152	34	11	1	4.3	8.3	0.1	0.9	0.2	0.4	0.0	0.3	0.1	217.6	0.5%
VENEZUELA	132	28	15	14	1.8	3.4	0.1	0.4	0.1	0.2	0.0	0.1	0.0	216.4	0.5%
ZAIRE	50	81	7	2	3.2	6.2	0.1	0.7	0.2	0.3	0.0	0.2	0.1	188.4	0.4%
PAKISTAN	70	26	6	4	10.1	19.6	0.2	2.1	0.5	0.9	0.0	0.8	0.2	176.5	0.4%
HUNGARY	60	8	3	8	3.5	12.6	0.2	1.0	0.2	0.5	0.1	0.4	0.1	123.4	0.3%
SWEDEN	34	30	2	4	4.4	12.1	0.9	8.4	0.3	0.5	0.0	0.4	0.1	98.0	0.2%
NEW ZEALAND	53	8	1	6	2.7	9.8	0.1	0.8	0.2	0.4	0.0	0.3	0.1	96.8	0.2%
SWITZERLAND	53	6	2	3	2.1	7.4	0.1	0.6	0.1	0.3	0.0	0.2	0.0	83.5	0.2%
FINLAND	53	6	2	3	2.1	7.4	0.1	0.6	0.1	0.3	0.0	0.2	0.0	75.3	0.2%
TAIWAN	0	2	0	4	2.0	4.0	0.1	0.4	0.1	0.2	0.0	0.2	0.0	13.5	0.0%
AFRICA	2005	635	180	57	59.6	116.2	2.1	12.6	2.8	5.6	0.5	4.5	1.1	3083.3	7.4%
OTHER LATIN AMERICA	1148	332	111	46	15.1	29.5	0.5	3.2	0.7	1.4	0.1	1.1	0.3	1689.1	4.0%
OTHER W. EUROPE	856	178	36	38	104.5	192.9	4.8	37.3	4.9	9.7	0.8	7.8	1.7	1472.4	3.5%
OTHER CP EUROPE	1054	41	45	24	26.1	115.2	1.4	8.5	1.9	4.0	0.3	3.0	0.8	1323.8	3.2%
OTHER S & E ASIA	703	436	63	16	23.7	46.2	0.8	5.0	1.1	2.2	0.2	1.8	0.4	1208.7	3.1%
OTHER CP ASIA	607	256	64	4	10.5	20.4	0.4	2.2	0.5	1.0	0.1	0.8	0.2	967.1	2.3%
MIDDLE EAST	524	69	18	31	11.6	22.6	0.4	2.5	0.6	1.1	0.1	0.9	0.2	681.9	1.6%
OTHER CENTRAL AMERICA	206	49	25	0	2.6	5.2	0.1	0.6	0.1	0.2	0.0	0.2	0.0	288.5	0.7%
WORLD TOTAL	25949	7713	2030	1422	974.1	2641.9	145.4	632.5	81.4	113.6	12.2	100.7	32.4	41848.4	100.0%

1985 EMISSION TOTALS BY GAS
(IN TERAGRAMS; ON A CO2-EQUIVALENT BASIS USING IPCC GWPS FOR 100-YEAR TIME HORIZON)

	CO2	CH4	N2O	CO	CFC-11	CFC-12	HCFC	CFC	CH3CCL3	CCL4	HALON	CFC-114	CFC-115	TOTAL EMISSIONS	%
AUSTRALIA	345	114	19	22	9.5	25.8	2.0	18.0	0.5	1.1	0.1	0.8	0.2	558.4	1.3%
BRAZIL	1394	482	155	32	13.8	27.0	0.5	2.9	0.7	1.3	0.1	1.0	0.2	110.4	5.0%
CANADA	469	81	25	50	10.6	37.9	0.5	3.1	0.7	1.5	0.2	1.2	0.2	680.5	1.6%
CHINA	2168	1028	160	67	7.1	42.1	0.4	2.9	0.7	1.4	0.0	1.2	0.4	478.8	8.3%
FEDERAL REP. GERMANY	754	119	28	47	68.2	100.6	3.2	25.3	2.9	5.6	0.4	4.6	1.0	1160.9	2.8%
FINLAND	53	6	2	3	2.1	7.4	0.1	0.6	0.1	0.3	0.0	0.2	0.0	75.3	0.2%
FRANCE	347	81	24	34	61.5	90.8	2.9	22.8	2.6	5.1	0.4	4.1	0.9	677.7	1.6%
HUNGARY	70	26	6	2	3.0	13.3	0.2	1.0	0.2	0.5	0.0	0.4	0.1	123.4	0.3%
INDIA	495	1011	56	28	5.1	30.2	0.3	2.1	0.5	1.0	0.0	0.9	0.3	1630.9	3.9%
INDONESIA	789	295	93	13	17.3	33.6	0.6	3.7	0.8	1.6	0.2	1.3	0.3	1249.6	3.0%
ITALY	342	41	16	23	63.8	94.2	3.0	23.7	2.7	5.3	0.4	4.3	1.0	619.8	1.5%
JAPAN	894	97	28	52	72.5	197.2	15.1	137.4	4.1	8.2	0.5	6.4	1.7	1515.4	3.6%
MEXICO	381	88	29	29	8.6	16.9	0.3	1.8	0.4	0.8	0.1	0.7	0.2	556.5	1.3%
NETHERLANDS	146	40	7	7	16.3	24.1	0.8	6.0	0.7	1.3	0.1	1.1	0.3	252.0	0.6%
NEW ZEALAND	34	30	2	4	4.4	12.1	0.9	8.4	0.3	0.5	0.0	0.4	0.2	96.8	0.2%
PAKISTAN	50	81	7	4	10.1	19.6	0.4	2.1	0.3	0.9	0.1	0.8	0.1	391.2	0.9%
PHILIPPINES	240	101	27	4	5.7	11.2	0.2	1.2	0.3	0.5	0.1	0.4	0.3	176.5	0.4%
POLAND	432	123	18	6	10.6	46.7	0.6	3.5	0.8	1.6	0.1	1.2	0.3	643.7	1.5%
SOUTH AFRICA	335	68	9	9	3.4	6.6	0.1	0.7	0.2	0.3	0.0	0.3	0.1	433.5	1.0%
SOUTH KOREA	161	35	6	1	4.3	8.3	0.1	0.9	0.2	0.4	0.0	0.3	0.1	217.6	0.5%
SWEDEN	60	8	3	8	3.5	12.6	0.2	1.0	0.2	0.5	0.0	0.3	0.1	98.0	0.2%
SWITZERLAND	53	8	1	6	2.7	9.8	0.1	0.8	0.2	0.4	0.0	0.2	0.1	83.5	0.2%
TAIWAN	0	2	0	4	2.0	4.0	0.1	0.4	0.1	0.2	0.0	0.4	0.1	13.5	0.0%
THAILAND	394	227	44	5	5.4	10.5	0.2	1.1	0.3	0.5	0.0	0.4	0.1	688.9	1.6%
UNITED KINGDOM	545	91	25	38	63.2	93.3	3.0	23.4	2.7	5.2	0.4	4.3	1.0	894.3	2.1%
UNITED STATES	4588	741	518	567	168.7	775.3	95.1	241.1	39.4	30.2	5.2	35.9	16.6	7822.0	18.7%
USSR	3490	722	168	132	78.6	346.8	4.2	25.7	5.8	12.2	0.8	9.2	2.3	4997.4	11.9%
VENEZUELA	152	34	11	14	1.8	3.4	0.1	0.4	0.1	0.2	0.0	0.1	0.0	216.4	0.5%
ZAIRE	132	28	15	2	3.2	6.2	0.1	0.7	0.2	0.3	0.0	0.2	0.1	188.4	0.5%
AFRICA	2005	635	180	57	59.6	116.2	2.1	12.6	2.8	5.6	0.5	4.5	1.1	3083.3	7.4%
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NEW ENERGY AND INDUSTRIAL TECHNOLOGY
DEVELOPMENT ORGANIZATION

WASHINGTON OFFICE

HEAD OFFICE
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NO. 1-1, HIGASHI-IKEBUKURO 3 CHOME
TOSHIMA-KU, TOKYO 170, JAPAN
TOKYO (03) 961-1511

1800 K STREET, NORTHWEST
WASHINGTON, D.C. 20006
(202) 822-9298

August 23, 1990

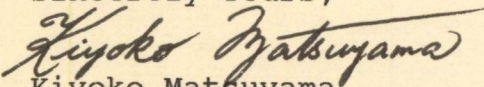
Mr. Jeff Holmstead
Assistant Counsel to the President
Old Executive Office Building 112
17th St. and Pennsylvania Avenue, N.W.
Washington, D.C. 20500

Mr. Holmstead:

Enclosed is a copy of "Formulation of the Government's Policy on
Global Warming" about which Mr. Yamamoto told you over phone.

Thank you very much for your continuing cooperation.

Sincerely Yours,


Kiyoko Matsuyama
NEDO Washington Office

FORMULATION OF THE GOVERNMENT'S POLICY ON GLOBALWARMING

On June 18, the Council of Ministers for Global Environment Conservation made a decision titled "Formulation of the Government's Policy on Global Warming" (See Annex I).

1. the main points are as follows:

- (1) The Council will formulate, by early autumn of 1990, an "Action Program to Arrest Global Warming" which includes near-term measures for global warming so that Japan can act appropriately within international developments in this field;
- (2) appropriate concrete targets for the stabilization of greenhouse gas emissions should be established after a full examination in order to achieve stabilization of greenhouse gas emissions at their lowest possible level by the year 2000, while bearing in mind the Noordwijk Declaration; and
- (3) aiming at social and economic systems which are compatible with the global environment, Japan will internationally advocate the formulation of a global and long-term vision.

2. (1) Japan will not be complacent with the achievement it has already made, i.e., the world's most

4/12

- 2 -

energy efficient economy (See Annex II). Japan will move further forward as the Council's decision of today clearly indicates.

(2) It is expected that the Ministries and Agencies concerned should make the utmost efforts to formulate the "Action Program", and the target of stabilization of greenhouse gas emissions by the year 2000 at the lowest possible level.

(3) The formulation of the "Action Program" and other measures will contribute to the international endeavors being made to prevent global warming.

(Unofficial translation)

FORMULATION OF THE GOVERNMENT'S POLICY ON GLOBALWARMING

-- A decision made by the Council of Ministers for Global Environment Conservation, on June 18, 1990

Although scientific uncertainty remains, global warming is a grave concern which could pose a serious threat to the very foundation of human life on earth. Therefore it is important to address this issue properly without delay, while making further efforts to increase the world's scientific knowledge with regard to this phenomenon.

Japan's basic policy is to participate actively in international endeavors to address global warming, the Intergovernmental Panel on Climate Change (IPCC) in particular, and thus contribute to efforts to formulate an international framework for concerted action. In this context, it is essential that Japan itself start to undertake all feasible measures immediately.

In dealing with the global warming problem, the wisdom of humankind should be gathered, and systematic and comprehensive measures to protect the world's environment should be taken from the long-term and global viewpoint.

Based on these considerations, the Government of Japan will take the following steps to formulate its policy.

I Action Program to Arrest Global Warming

The Council of Ministers for Global Environment Conservation will formulate, by early autumn of 1990, an Action Program To Arrest Global Warming (hereafter referred to as "Action Program") which include near-term measures concerning global warming so that Japan can act appropriately within international developments in this field.

The Action Program will be revised as necessary and acted on flexibly, based on international developments and scientific progress.

1. Objectives of the Action Program

The Action Program aims at defining the government's near-term policy as well as the overall picture with regard to feasible measures to be taken to promote effective responses to global warming in a systematic and comprehensive manner. This is intended to increase public understanding and cooperation and to establish the government's basic position towards contributing to international efforts to create a framework for concerted action.

Each government ministry and agency should play an active role in formulating for the Action Program and make every effort to steadily implement the measures adopted in line with this Action Program while obtaining the understanding and cooperation of all segments of the nation.

7/12

2. Framework of the Action Program

1) Goals of the Action Program

- a) Need to Stabilize Emissions of Carbon Dioxide (CO₂) and Other Greenhouse Gases, etc.

The atmospheric concentrations of CO₂ and other greenhouse gases are increasing yearly raising serious concern about the impact of such concentrations on the environment. The Noordwijk Declaration on Climate Change states that the participants agree on the need to stabilize the emissions of CO₂ and other greenhouse gases while ensuring the stable development of the world economy. It also was internationally agreed upon that such stabilization should be achieved by the industrialized nations as soon as possible at levels to be considered by the IPCC and the Second World Climate Conference scheduled for November 1990. Further it is agreed in, this Declaration, inter alia, that countries pursue a global balance between deforestation on one hand and sound forest management and afforestation on the other.

Keeping in mind the latest international developments, including the agreement reached at Noordwijk, Japan will endeavor to stabilize as soon as possible the emission of CO₂ and other greenhouse gases while ensuring the stable development of the economy and also to expand sinks of CO₂ by such measures as forest conservation and afforestation on a global scale, etc.

b) Target Setting

Appropriate concrete targets for stabilization of greenhouse gas emissions should be established and included in the Action Program for use as guidelines after a full examination in order to achieve stabilization of greenhouse gas emissions at the lowest possible level by the year 2000, while bearing in mind the Noordwijk Declaration. Such examinations should reflect international developments on global warming issues, the accumulation of knowledge, Japan's role in the world economy, proper management of the country's economy, the desirable life style of its people and other matters.

2) Duration of the Action Program

The Action Program covers, for the time being, the period from 1991 to 2010. The duration will be further divided into appropriate sub-periods.

3) Measures To Be Taken

The measures and the means for their implementation to be included in the Action Program should extend to a wide array of policy areas such as energy, transportation, urban policy, agriculture, forestry and fishery. The measures and the means of their implementation should be examined with the objective to limit the emission of greenhouse gases including CO₂ to the greatest extent possible and to increase their sinks, while considering their impact on the economy and other factors.

- a) Limitation of greenhouse gas emissions
 - Promotion of energy and resource conservation
 - Introduction and wide use of energy source with no or low CO2 emissions
 - Limitation of emissions of methane and other greenhouse gases
- b) Conservation and provision of greenhouse gas sinks, e.g., reforestation and tree planting
- c) Promotion of scientific research and observation/monitoring to improve knowledge about the mechanisms of global warming, predictive capacity, etc.
- d) Development and dissemination of CO2 fixation and reutilization and other technologies
- e) Raising public awareness, promoting environmental education and other measures which support arresting of global warming
- f) Promoting international cooperation
- 4) Implementation of the measures described above under 3)

II Global Long-term Vision to Arrest Global Warming

It is also important for all countries of the world to deal with the global warming problem in a comprehensive and concerted manner under a long-term perspective. In view of this, aiming at social and economic systems which

are compatible with the global environment, Japan will internationally advocate formulation of a global and long-term vision extending over the next hundred years (e.g., New Earth 21). The Ministries and Agencies concerned will make necessary deliberations to have an international understanding on such a worldwide vision. The vision should include the following elements.

- Strengthening of the scientific basis
- Promotion of energy and resources conservation
- Widespread introduction of clean energy
- Development of innovative environmental technology
- Large-scale expansion of greenhouse gas sinks by e.g. reforestation and conservation of tropical forests
- Development of future generation energy technologies

Annex II

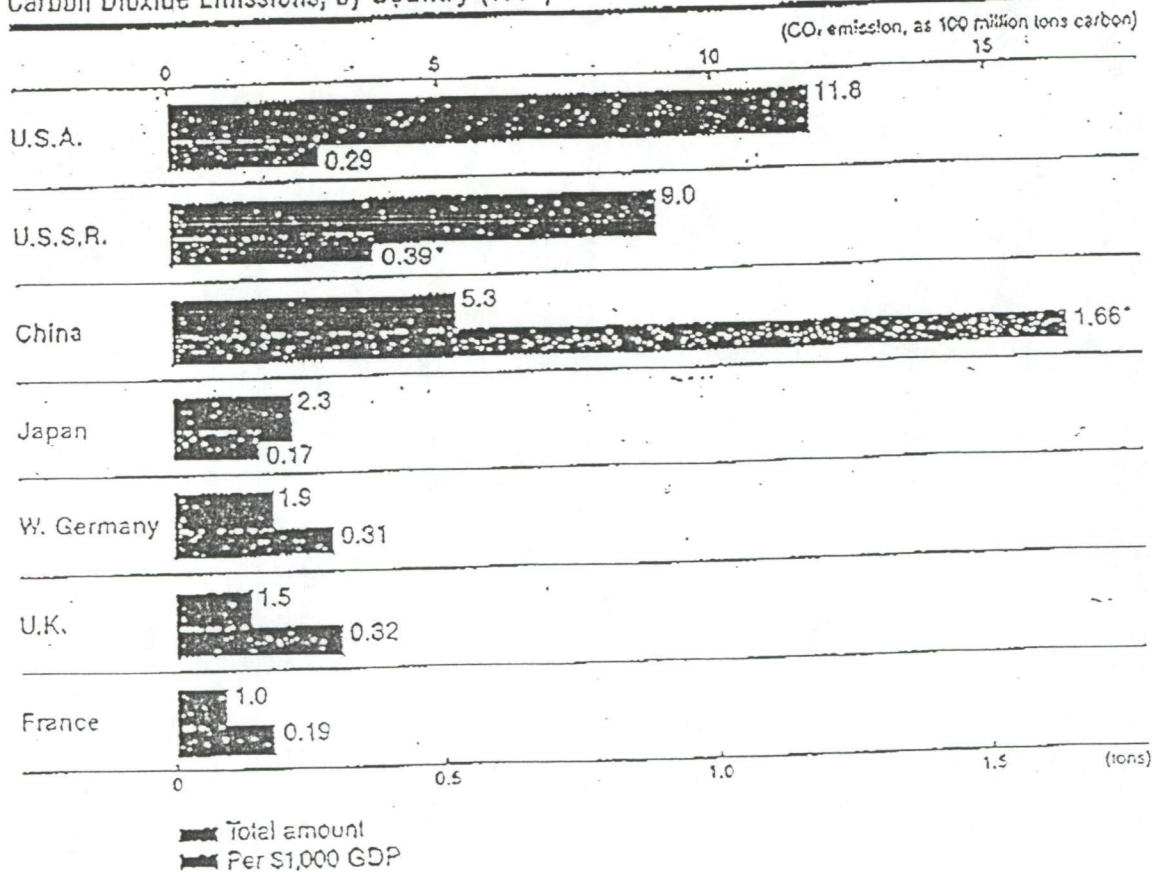
Energy Consumption Intensity per GDP (1987)

	Tons (crude-oil equivalent) /US\$ millions*	Average annual decrease (% 1973-87)
France	379	1.2
Italy	329	1.7
Japan	262	2.8
U.K.	431	2.0
U.S.A.	441	2.1
W. Germany	419	1.6

*1985 data

Source: OECD Energy Balances

Carbon Dioxide Emissions, by Country (1985)



*Based on GNP data

Note: The total CO₂ emission in 1985 was 52.5.

Sources: Energy Technologies for Reducing Emissions of Greenhouse Gases, OECD, 1989 (carbon dioxide emissions); International Financial Statistics (GDP); CIA Economic Statistics Handbook (Soviet GNP); World Bank Atlas (China GNP)

FORMULATION OF THE GOVERNMENT'S POLICY ON GLOBAL WARMING

On June 18, the Council of Ministers for Global Environment Conservation made a decision titled "Formulation of the Government's Policy on Global Warming" (see Annex I).

1. The main points are as follows:

- (1) The Council will formulate, by early autumn of 1990, an "Action Program to Arrest Global Warming", which will include near-term measures for global warming so that Japan can act appropriately within international developments in this field;
- (2) appropriate concrete targets for the stabilization of greenhouse gas emissions should be established after full examination to achieve stabilization of greenhouse gas emissions at their lowest possible level by the year 2000, while bearing in mind the Noordwijk Declaration; and
- (3) in view of the importance for all countries of the world to deal with the global warming problem in a comprehensive and concerted manner under a long-term perspective, Japan will internationally advocate the formulation of a global and long-term strategy, i.e. "The New Earth 21".

2.(1) Japan will not be complacent with the achievement it has already made, i.e. the world's most energy efficient economy (see Annex II). Japan will continue to move forward, as the Council's decision clearly indicates.

(2) It is expected that the ministries and agencies concerned should make the utmost effort to formulate the "Action Program", and the target of stabilization of greenhouse gas emissions by the year 2000 at the lowest possible level.

(3) "The New Earth 21" initiative, as well as the "Action Program" and other measures, will contribute to the international endeavors being made to address global warming.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

January 18, 1991

MEMORANDUM FOR JEFFREY HOLMSTEAD
OFFICE OF WHITE HOUSE COUNSEL

FROM:

Charles Dickens
for MARYANNE C. BACH
EXECUTIVE DIRECTOR, FCCSET

SUBJECT: REVIEW OF FCCSET REPORT ON GLOBAL CHANGE
RESEARCH

Attached for your review and comment is a draft version of the report "Our Changing Planet: The FY 1992 U.S. Global Change Research Program," prepared by the Committee on Earth and Environmental Sciences of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET).

This report has been reviewed by the Committee, and OMB is currently conducting a review with the participating departments and independent agencies.

Please provide any comments you may have to me or Charles Dickens by close of business on Tuesday, January 22. We may be reached at 395-5101 (FAX 395-1575). If you note any items of immediate concern, please call the FCCSET Directorate as soon as possible.

We appreciate your cooperation. If you have any questions, please contact the FCCSET Directorate as soon as possible.

Attachment

cc: Nancy Maynard, OSTP

Our Changing Planet:
The FY 1992
U.S. Global Change Research Program

**A Report by the Committee on Earth and Environmental
Sciences**

**To Accompany the
U.S. President's Fiscal Year 1992 Budget**

**Office of Science and Technology Policy
Federal Coordinating Council for Science,
Engineering and Technology**

Committee on Earth and Environmental Sciences

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Dallas L. Peck, Department of the Interior, United States Geological Survey

Vice-Chairmen

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Lennard A. Fisk, National Aeronautics and Space Administration

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W. F. Willis, Tennessee Valley Authority
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G. Robert Fuller, Department of Housing and Urban Development
William Roper, Department of Health and Human Services
Harold R. Denton, Nuclear Regulatory Commission

Executive Secretary

Paul V. Dresler, Department of the Interior, United States Geological Survey
Jerry W. Elwood, CEES Staff
Hannah E. Sluss, CEES Secretary

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
Washington, D.C. 20506

MEMBERS OF CONGRESS:

I am pleased to forward with this letter "Our Changing Planet: The FY 1992 U.S. Global Change Research Program," a report by the Committee on Earth and Environmental Sciences of the Federal Coordinating Council for Science, Engineering, and Technology to accompany the President's Fiscal Year 1992 Budget.

The report outlines an accelerated, focused research strategy designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound policies and responses to global change can be based. Because of the importance of this area, the President is proposing a 24.2 percent increase in the budget for this effort for FY 1992.

The research program presented here is a key component of the President's overall approach to the global change issue. This approach has, as its central goal, the provision of a sound scientific basis for developing national and international policy on global change. The President has called for an expanded schedule of international collaboration on research, monitoring, and data exchange. This comprehensive approach recognizes the profound economic and social implications of responding to global environmental changes and maintains U.S. leadership on this issue.

The Committee on Earth and Environmental Sciences' report outlines a careful blend of ground- and space-based efforts in research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. The report has benefited from close interaction with the National Academy of Sciences, the International Council of Scientific Unions' International Geosphere-Biosphere Programme, and the World Meteorological Organization's World Climate Research Programme. As such, I believe the report and the process which produced it provide an exemplary model of a coordinated, integrated research strategy and a sound basis for planning. Dr. Dallas Peck, Chairman of the Committee on Earth and Environmental Sciences (CEES), and Dr. Robert Corell, Chairman of the CEES Working Group on Global Change, and their interagency committee members, associates, and staff have done an excellent job and are to be commended.

Sincerely,

D. Allan Bromley
Director

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
OVERVIEW	3
RESEARCH PROGRAM AND BUDGET	9
BUDGET OVERVIEW	9
BUDGET BY INTEGRATING THEMES	9
Policy Relevance of Integrating Themes	9
Climate Modeling and Prediction	15
Global Water and Energy Cycles, including Sea Level Change	17
Global Carbon Cycle	21
Ecological Systems and Population Dynamics	26
Other Research Activities	30
BUDGET BY SCIENCE ELEMENT	34
BUDGET BY SCIENTIFIC OBJECTIVE	35
BUDGET BY AGENCY	36
BUDGET BY FEDERAL BUDGET FUNCTION	39
SPECIAL ISSUES	40
DATA AND INFORMATION SERVICES	40
SPACE-BASED RESEARCH	41
ECONOMICS RESEARCH RELATED TO GLOBAL CHANGE	43
EDUCATION, TRAINING & HUMAN RESOURCES	46
INTERNATIONAL DIMENSIONS	46
EVOLVING PRIORITIES	47
PROGRAM MANAGEMENT & EVALUATION	47
APPENDIX	49

THE FY 1992 GLOBAL CHANGE RESEARCH PROGRAM EXECUTIVE SUMMARY

- o World leaders continue to debate the economic and social implications of global environmental changes, both natural and human-induced.
- o An improved predictive understanding of the integrated Earth system, including human interactions, will provide direct benefits by anticipating and planning for impacts on commerce, agriculture, energy, resource utilization and human safety.
- o The central goal of the U.S. Global Change Research Program (USGCRP) is to establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system, by:
 - Establishing an integrated, comprehensive, long-term program of documenting the Earth system on a global scale;
 - Conducting a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes;
 - Developing integrated conceptual and predictive Earth system models.
- o The highest priority policy issue for the USGCRP in FY 1992 is whether, and to what extent, changes in the global climate system justify significant energy and environmental policy changes.
- o The FY 1992 USGCRP responds to the most critical scientific uncertainties identified by the Scientific and Impacts Working Groups of the Intergovernmental Panel on Climate Change (IPCC) as the highest priority near-term foci.
- o Using the information needs identified by the IPCC, the USGCRP adopted four high priority Integrating Themes for FY 1992:
 - Climate Modeling and Prediction
 - Global Water and Energy Cycles
 - Global Carbon Cycle
 - Ecological Systems and Population Dynamics
- o The Integrating Themes allow the USGCRP to focus the collective efforts of government and academic scientists, in collaboration with scientists from other countries, on high-priority, multi-disciplinary investigations in order to:
 - Develop an improved predictive capability of the Earth as a coupled system with enhanced regional resolution;
 - Improve the understanding of the water and energy cycles by focusing on the role of clouds, oceans, terrestrial ecosystems, and changes in sea level;
 - Improve the understanding of the carbon cycle by quantifying sources and sinks, the processes that control them, and how the processes may influence and be influenced by global change;
 - Improve the capacity to assess the effects of global change at regional scales on intensively managed and natural terrestrial and oceanic ecosystems.

- o The USGCRP also enhances support for economics research, and includes continued support for investigations in stratospheric ozone, biodiversity, human interactions, solid earth processes, and solar influences.
- o The President's FY 1992 Budget requests \$1185.5 million for the USGCRP. This represents an increase of \$231.3 million, or 24.2 percent, over the FY 1991 Congressional appropriations for all participating agencies.
- o The USGCRP has been developed through the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). It has been established in cooperation with the U.S. and international scientific communities, through the National Academy of Sciences (NAS), the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO), and is linked internationally to other government agencies, to the relevant intergovernmental organizations of the United Nations, and to other governmental and non-governmental organizations.

THE FY 1992 U.S. GLOBAL CHANGE RESEARCH PROGRAM OVERVIEW

Background

World leaders continue to debate the economic and social implications of global environmental changes, both natural and human-induced. The 1988 midwestern U.S. drought underscored the potential effects of a warm, dry summer, just as the climate of recent decades in the Sahel starkly reveals the human tragedy that can occur in marginal-subsistence zones of a changing planet. Furthermore, the linking of the Antarctic ozone "hole" to man-made chlorofluorocarbons (CFC's) and the current debate over humanity's role in the "greenhouse effect" have placed the environment high on the national and international agenda. The substantial costs associated with addressing global environmental changes require policy decisions be based on adequate scientific knowledge. In virtually all these issues, the salient feature is the significant scientific uncertainty associated with predicting the behavior of the coupled ocean-atmosphere-land Earth system. To reduce this uncertainty, the USGCRP has been developed as a central component of the U.S. Government's approach to global environmental change.

The USGCRP has been developed by the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). With strong support from the national and international scientific communities, the Federal agencies (Council of Economic Advisors (CEA), Department of Commerce/National Oceanic and Atmospheric Administration (DOC/NOAA), Department of Defense (DOD), Department of Energy (DOE), Department of the Interior (DOI), Department of State (DOS), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), Office of Management and Budget (OMB), Smithsonian Institute (SI), and the Department of Agriculture (USDA)), under the auspices of the White House Office of Science and Technology Policy's CEES, formally established the USGCRP as a Presidential initiative in the FY 1990 Budget. The USGCRP is driven by carefully established priorities that must be addressed to establish sound national and international policies related to global environmental issues, particularly global climate change. It has been established in cooperation with the U.S. and international scientific communities, through the National Academy of Sciences (NAS) and the International Council of Scientific Unions (ICSU). The USGCRP is also linked internationally to intergovernmental organizations, such as the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission (IOC), and to a number of agencies of other governments through the informal International Group of Funding Agencies (IGFA) for Global Change Research, and space agencies through the Committee on Earth Observations Satellites (CEOS).

The overarching and long-term goal of the USGCRP is:

To establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system.

To meet this goal, the CEES Global Change Working Group has established the following overall objectives for the USGCRP:

- o To establish an integrated, comprehensive, long-term program of documenting the Earth system on a global scale;
- o To conduct a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales; and

- o To develop integrated conceptual and predictive Earth system models.

Work towards these objectives proceeds simultaneously and in concert since progress in each influences the others. It is recognized that the goal and objectives can only be achieved through the mutually-reinforcing research activities of all nations and many organizations and programs which require a large measure of bilateral and multilateral cooperation.

The structure of the USGCRP draws upon the strengths of existing, fundamental disciplines to develop the interdisciplinary scientific approaches that an integrated global change research program demands. The Program's seven science elements reflect the integrated and interdisciplinary nature of such a complex research effort. These science elements are (in descending priority order):

- Climate and Hydrologic Systems
- Biogeochemical Dynamics
- Ecological Systems and Dynamics
- Earth System History
- Human Interactions
- Solid Earth Processes
- Solar Influences.

The ultimate success of the USGCRP requires progress in all seven scientific elements, as well as the development of data and information management systems, to facilitate the organization and analysis of integrated data sets.

During the past two years, the CEES has adopted an integrated and priority-driven framework (Figure 1) to guide the development of the USGCRP. Within the priority framework, the CEES evaluates the proposed projects on the basis of (i) their relevance and contribution to the overall USGCRP goal and objectives; (ii) scientific merit as documented by peer review; (iii) readiness for implementation and likelihood of early results; (iv) linkages to other national and international programs; (v) costs in the short- and long-term; (vi) enhancements to existing high-priority programs before starting new initiatives; and (vii) agency approval for inclusion in the USGCRP. The framework and the evaluation criteria are an essential part of the program and budget development strategy of the CEES and provides the structure within which CEES evaluates and develops: (1) the essential, high priority national and international components of the USGCRP in each fiscal year; and (2) the recommended budgets to support those critical components. This enables CEES to develop and recommend an evolving USGCRP which supports U.S. global change policy interests.

The FY 1992 Program

The USGCRP was developed in response to the evolving nature of Earth science research to a more multidisciplinary or "Earth System Science" approach. The foundation of Earth System Science is the belief that sound scientific information on global change must be derived from a comprehensive, integrated view of the interactions among key components of the Earth system, and the influence of human activities on them. However, the overall constraints on Federal funding associated with the FY 1991 deficit reduction agreement led the CEES to pursue a program more focused on the highest priority scientific and policy issues over the next few years. In particular, the highest priority scientific and policy issue for the USGCRP in FY 1992 was to determine if changes in the global climate system justify significant energy and environmental policy changes, and what influences human activities have on these changes.

In this context, the CEES relied on the results of the Scientific and Impacts Assessments of the Intergovernmental Panel on Climate Change (IPCC) in developing the FY 1992 Program. Specifically, the FY 1992 USGCRP will:

- (1) Enhance scientific research effort that seek to reduce the scientific uncertainties identified during the IPCC scientific and impacts assessments, especially:
 - o sources and sinks of greenhouse gases, which affect predictions of future concentrations;
 - o clouds and radiative balance, which strongly influence the magnitude of climate change at global and regional scales;
 - o oceans, which influence the timing and patterns of climate change;
 - o land-surface hydrology, which affects regional climate change and water availability;
 - o polar ice sheets, which affect predictions of global sea level changes; and
 - o ecological dynamics, which are impacted by and respond to climate change; and
- (2) Enhance scientific research to address greenhouse gases comprehensively, rather than on a gas-by-gas basis. Priorities include:
 - o sources and sinks of greenhouse gases;
 - o development of a quantitative index of radiative forcing; and
 - o development and use of economic models to generate predictions and scenarios that cover multiple greenhouse gases and multiple economic sectors.

For FY 1992, many of the proposed augmentations to the USGCRP explicitly support international research activities and regional-scale U.S. research activities that will address the issues identified by the IPCC, and give high-priority support for the following World Climate Research Programme (WCRP) and International Geosphere Biosphere Programme (IGBP) efforts: the Tropical Ocean and Global Atmosphere (TOGA) Program, the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Studies (JGOFS) Program, the International Global Atmospheric Chemistry (IGAC) Program, the Global Energy and Water Cycle Experiment (GEWEX), Biospheric Aspects of the Hydrologic Cycle (BAHC), Global Change and Terrestrial Ecosystems (GCTE), and Past Global Changes (PAGES). These activities direct resources to that portion of Earth system science where scientific advancement can contribute to decreases in uncertainty. This approach also fosters the international cooperation essential to rapidly achieve scientific understanding.

Planning for the FY 1992 USGCRP, like in previous years, has been guided by the extensively reviewed strategic, integrating, and scientific priorities of the planning framework (Figure 1) and the evaluation criteria. The results of the IPCC scientific and impacts assessments were utilized in developing the USGCRP to ensure that the Program is responsive to the highest priority global change policy issues. Pursuing a Program focused on these IPCC scientific and impacts issues in the near-term will require continued interaction with the national and international scientific communities in discussions of scientific priorities. Using the information needs identified by the IPCC as a guide, four high priority FY 1992 programmatic Integrating Themes

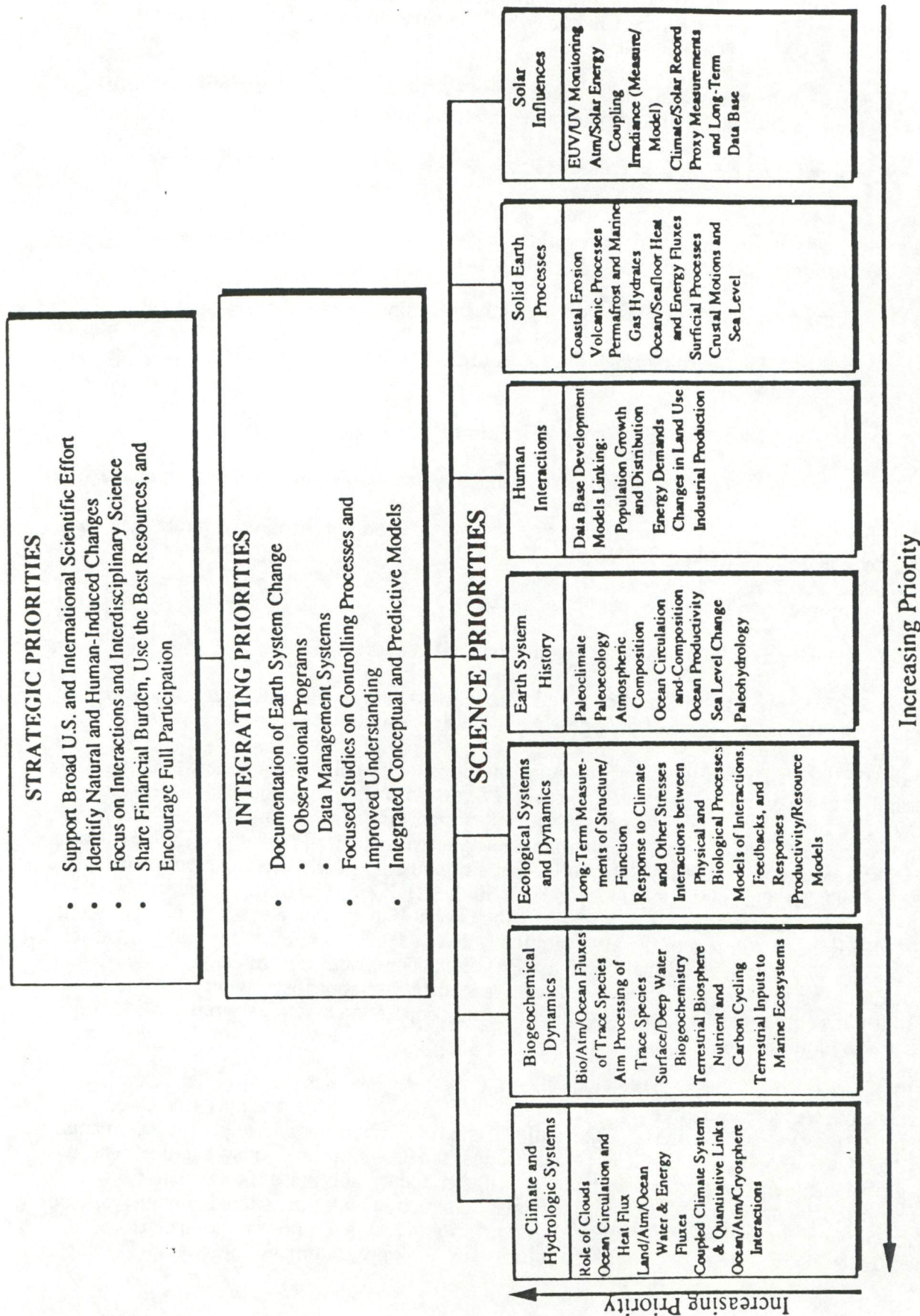


Figure 1 U.S. Global Change Research Program Priority Framework

were adopted: (i) Climate Modelling and Prediction; (ii) the Global Water and Energy Cycles, including global sea level change; (iii) the Global Carbon Cycle; and (iv) Ecological Systems and Population Dynamics. Addressing these themes requires efforts in most of the seven science elements (including Human Interactions) and, therefore, provides an enhanced level of integration for the Program. These FY 1992 Integrating Themes allow the CEES agencies to focus the collective efforts of government and academic scientists, in collaboration with scientists from other countries, on a number of high priority, multi-disciplinary investigations which respond to some of the current critical information needs in global change.

The four FY 1992 Integrating Themes are:

- (i) *Climate Modelling and Prediction:* To develop an improved predictive capability of the Earth as a coupled system with enhanced regional resolution; with initial priority given to the climate system.
- (ii) *Global Water and Energy Cycles:* To improve the understanding of the water (precipitation, evaporation, evapotranspiration, soil moisture, ice quantity, type and movement) and energy cycles (warming/cooling, radiative balance, solar variability, latent heat), by focusing on the:
 - role of clouds: primarily the role of water vapor and cloud formation, dissipation and radiative properties;
 - role of the oceans: the exchange of energy and mass (e.g., water) between the ocean, sea ice, and the atmosphere; between the upper layers of the ocean and the deep ocean; and transport within the ocean;
 - role of terrestrial ecosystems: the exchange of energy and water between the surface, including managed and natural terrestrial ecosystems and soils, and the atmosphere; and
 - change in sea level, which is an integrated Earth system response to changing climate conditions, by examining the role of polar ice sheets and thermal expansion of the oceans and melting of land glaciers.
- (iii) *Global Carbon Cycle:* To improve the understanding of the carbon cycle, by:
 - quantifying the natural and anthropogenic terrestrial and oceanic sources and sinks of key carbon compounds (e.g., carbon dioxide (CO₂), methane (CH₄) and ozone (O₃) precursors such as carbon monoxide (CO) and the non-methane hydrocarbons (NMHC's)), including their chemical reactions in the atmosphere and oceans, the chemical, biological and physical processes that control their fluxes, how these may be influenced by climate change, and how changes in greenhouse gas abundances affect the magnitude and rate of change;
- (iv) *Ecological Systems and Population Dynamics:* To improve the capacity to assess the effects of global change at regional scales, specifically to:
 - improve understanding of the responses of intensively managed and natural oceanic and terrestrial ecosystems to global change by focusing scientific research on:
 - species composition of ecosystems;

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- distribution and extent of ecosystems; and
- productivity of ecosystems.

The four Integrating Themes for FY 1992, and the agency projects which support them, do not, however, represent the USGCRP in its entirety. While these Integrating Themes provided a principal focus for major funding enhancements in FY 1992, the President's Budget request also includes resources to maintain programmatic momentum in a number of other critical USGCRP investigations. These include continued support for investigations in the areas of stratospheric ozone, biodiversity, human interactions, solid earth processes, and solar influences. Detailed information regarding FY 1992 USGCRP plans in these areas follow the discussion of the Budget by Integrating Theme.

Research Program and Budget

Budget Overview

Table 1 shows the USGCRP budget by integrating theme and by agency; Table 2 shows the USGCRP by science element and by agency; and Table 3 shows the USGCRP by scientific objective. The FY 1991 enacted funding for the USGCRP is \$954.2 million. The President's FY 1992 budget proposes a funding level of \$1185.5 million, a \$231.3 million (24.2 percent) increase over the FY 1991 enacted level. Table 4 shows the budgets for programs that contribute to global change research and provide important support to the Program objectives but were initiated for reasons other than the focused Program goal.

Budget by Integrating Theme

This section summarizes the FY 1992 activities in the four integrating themes, i.e., (i) climate modeling and prediction; (ii) global water and energy cycles, including sea level change; (iii) global carbon cycle; (iv) and ecological systems and population dynamics. A few critical USGCRP activities do not fit within one or more of these integrating themes, e.g., stratospheric ozone processes, solid Earth processes, solar processes, and economics research. These activities are briefly described in either the "other research activities" or special issues sections.

Table 1 and Figure 2 show the FY 1991 enacted and FY 1992 proposed budgets for the USGCRP by integrating theme.

Policy Relevance of Integrating Themes

The global changes of primary concern to national and international policy makers are those that could impact the Earth's life-support system. Prudent environmental policy formulation will require a defensible scientific understanding of how the Earth system, hydrologic cycle, carbon cycle, and biological resources vary naturally, how human activities change them, and how they might respond to future changes in environmental conditions. Central to this concern are questions about the Earth's future climate, such as the global and regional distributions of temperature, precipitation and storm frequency and intensity, including the question of climate change due to greenhouse warming. Of equal concern are questions about changes in the Earth system that may result from future climates, such as sea level, biological productivity and diversity, and the chemical composition and water storage capacity of soils. The task of predicting the biological impacts of both climate and other environmental changes is made more difficult by the complexity of interactions and feedbacks among these components.

Climate Modeling and Prediction

The ultimate goal of the USGCRP is to support national and international policymaking by developing the ability to predict the nature and consequences of changes in the Earth system, particularly climate change. Understanding and predicting changes in the Earth system requires that many distinct research components be successfully linked. The atmosphere, the ocean, the cryosphere, the land surface, and terrestrial and marine ecosystems all operate together as a complex interrelated system. The Earth system is too complex to allow direct experiments that would yield reliable predictions of future environmental changes. Therefore, simplified predictive models are used to simulate the physical, geological, chemical and biological processes governing the behavior of the Earth system. Because of an insufficient understanding of key Earth system processes, and the inadequate capacity and speed of computers required to simulate the coupled ocean/atmosphere/land Earth system as a single entity, models that predict separately the

Table 1
FY 1991-1992 U.S. Global Change Research Program Focused Budget By Integrating Theme
 (Dollars in Millions)

Focused Program	Total Budget		Climate Modeling and Prediction		Global Water and Energy Cycles (Inc. Sea Level Change)		Global Carbon Cycle		Ecological Systems and Population Dynamics		Other Research Activities	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Agency Totals	954.2	1185.5	54.7	88.5	420.2	527.1	131.9	165.0	106.0	147.0	241.4	257.9
DOC/NOAA	47.0	78.0	11.3	20.2	28.1	46.1	5.4	7.2	0.6	2.4	1.6	2.1
DOO	0	6.3	0	0	0	4.8	0	0.3	0	1.0	0	0.2
DOE	65.6	77.0	21.9	26.5	27.2	32.0	16.5	18.5	0	0	0	0
DOI	36.6	46.4	4.3	4.9	18.1	20.7	4.8	5.0	8.1	14.0	1.3	1.8
EPA	21.8	26.0	0	0	0	0	12.2	14.8	6.3	7.4	3.3	3.8
NASA	651.6	772.6	14.9	27.9	312.5	377.7	57.6	70.5	51.2	72.1	215.4	224.4
NSF	87.1	118.5	0.0	3.5	31.9	42.9	23.2	32.3	12.9	19.5	19.1	20.3
SMITHSONIAN	5.9	7.5	0	0	0.1	0.1	1.2	1.9	3.9	4.5	0.7	1.0
USDA	38.6	53.2	2.3	5.5	2.3	2.8	11.0	14.5	23.0	26.1	0	4.3

Table 2
FY 1991-1992 U.S. Global Change Research Program Focused Budget
 (Dollars in Millions)

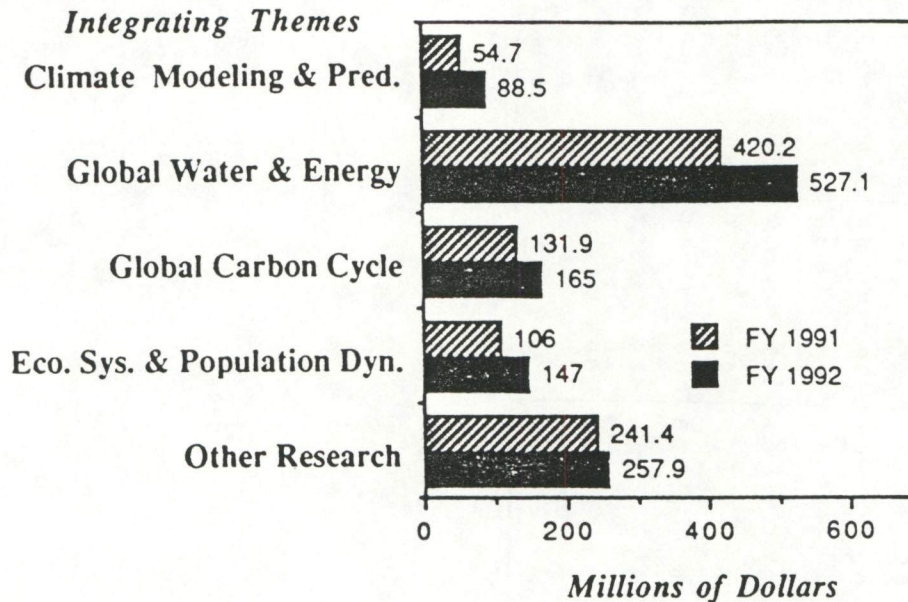
Focused Program	Total Budget		Climate & Hydrologic Systems		Biogeochemical Dynamics		Ecological Systems and Dynamics		Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Agency Totals	954.2	1185.5	450.7	582.1	249.1	280.9	140.4	188.4	18.2	21.4	28.3	29.0	53.7	66.5	13.8	17.2
DOC/NOAA	47.0	78.0	37.3	63.0	7.4	10.4	0.6	2.4	1.7	2.2	0	0	0	0	0	0
DOD	0	6.3	0	3.8	0	0.9	0	1.0	0	0.3	0	0	0	0.3	0	0
DOE	65.6	77.0	44.2	54.0	11.0	13.0	7.4	7.3	0	0	3.0	2.7	0	0	0	0
DOI	36.6	46.4	12.7	14.2	3.0	3.0	7.2	12.7	7.5	9.1	1.6	2.1	4.6	5.3	0	0
EPA	21.8	26.0	0	0	7.2	9.3	6.3	7.4	0	0	8.3	9.3	0	0	0	0
NASA	651.6	772.6	326.3	399.8	185.7	196.1	81.8	113.1	0.0	0.0	10.2	1.8	38.3	50.2	9.3	11.6
NSF	87.1	118.5	28.1	41.8	22.4	29.9	12.5	17.9	6.2	6.8	3.6	6.8	9.9	9.8	4.4	5.5
SMITHSONIAN	5.9	7.5	0	0	0.2	0.2	3.2	4.3	1.0	1.2	0.5	0.8	0.9	0.9	0.1	0.1
USDA	38.6	53.2	2.1	5.5	12.2	18.1	21.4	22.3	1.8	1.8	1.1	5.5	0.0	0.0	0.0	0.0

Table 3 FY 1991-1992 U.S. Global Change Research Program Focused Budget By Scientific Objective (Dollars in Millions)										
Focused Program	Total Budget		Observations		Data Management		Understanding		Prediction	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Agency Totals	954.2	1185.5	258.7	355.3	170.5	233.3	456.9	494.3	68.1	102.6
DOC/NOAA	47.0	78.0	12.7	22.5	7.1	12.8	17.6	24.7	9.6	18.0
DOD	0	6.3	0	1.0	0	0.5	0	3.7	0	1.1
DOE	65.6	77.0	19.4	27.0	2.0	2.0	28.5	29.8	15.7	18.2
DOI	36.6	46.4	13.6	16.5	5.6	7.1	14.8	19.2	2.6	3.6
EPA	21.8	26.0	0.2	0.4	0.1	0.2	19.4	20.9	2.1	4.5
NASA	651.6	772.6	194.4	259.5	147.7	198.8	288.2	284.0	21.3	30.3
NSF	87.1	118.5	7.7	10.1	6.0	8.5	64.5	83.8	8.9	16.1
SMITHSONIAN	5.9	7.5	1.7	2.3	0.5	0.7	3.6	4.4	0.1	0.1
USDA	38.6	53.2	9.0	16.0	1.5	2.7	20.3	23.8	7.8	10.7

Table 4
FY 1991-1992 Budget of Contributory Programs to the U.S. Global Change Research Program
 (Dollars in Millions)

Focused Program	Total Budget		Climate & Hydrologic Systems		Biogeochemical Dynamics		Ecological Systems and Dynamics		Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Agency Totals	086.2	1199.4	593.9	688.9	89.2	85.2	191.2	207.7	26.0	27.0	110.4	117.8	64.8	61.2	10.7	11.6
DOC/NOAA	433.4	531.6	405.1	504.4	16.3	16.3	6.0	4.8	0.4	0.4	0.1	0.2	4.7	4.7	0.8	0.8
DOD	31.0	28.9	22.1	22.7	1.1	1.1	6.0	3.9	0.0	0.0	0.0	0.0	1.8	1.2	0.0	0.0
DOE	40.4	42.3	0.0	0.0	24.7	25.1	7.0	6.5	0.0	0.0	0.0	2.0	7.7	7.7	1.0	1.0
DOI	253.3	252.9	105.4	97.6	3.4	3.4	57.9	60.4	0.3	0.3	78.3	83.2	6.3	6.3	1.7	1.7
EPA	46.2	48.2	7.2	5.2	1.0	1.0	38.0	42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASA	25.3	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.3	20.0	0.0	0.0
NSF	132.5	144.4	47.2	50.3	26.6	27.1	20.8	25.3	24.3	25.0	4.9	5.1	3.6	5.6	5.1	6.0
SMITHSONIAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
USDA	124.1	131.1	6.9	8.7	16.1	11.2	55.5	64.8	1.0	1.3	27.1	27.3	15.4	15.7	2.1	2.1

Figure 2
U.S. Global Change Research Program Budget
by Integrating Themes



components of future environments are currently used. The central task of the USGCRP is to understand the processes and integrate the predictions from these various models to provide leaders of governments with the best possible scientific information as input to environmental policy decisions.

Global Water and Energy Cycles, including Sea Level Change

The global hydrologic cycle plays a pivotal role in the Earth's radiation and heat budgets. The distribution of clouds and water vapor, for example, play a key role in controlling the amount of solar energy absorbed by the Earth system as well as the infrared radiation emitted to space, and they strongly influence the redistribution of heat throughout the Earth system. The future availability of adequate water supplies is the most significant natural resource issue in many regions throughout the world. Any substantial rise in sea level would have major economic impact on low-lying coastal areas, resulting in erosion, inundation, and/or wetland loss. The USGCRP is pursuing a broadly-based suite of projects addressing important aspects of the global water and energy cycle problem. These projects include the study of atmospheric water vapor (the most radiatively active gas in the atmosphere), clouds and their role in climate system feedbacks, precipitation and its distribution over land and sea, changes in sea ice extent and amount, the role of the oceanic circulation in absorbing gases and redistributing heat, and the interaction of terrestrial ecosystems with the atmosphere.

Global Carbon Cycle

Human activities are resulting in significant alterations in the biogeochemical cycling and partitioning of carbon throughout the Earth's environment. There is now unambiguous scientific evidence that the atmospheric concentrations of several key radiatively and chemically active gases, such as carbon dioxide and methane, are increasing primarily due to human activities, therefore, increasing the total radiative forcing of the atmosphere. Other gases, such as carbon monoxide and possibly non-methane hydrocarbons, the oxides of nitrogen (NO_x), and ozone are also increasing, and these gases have important roles in photochemistry and the lifetimes of methane and other radiatively active gases. There are significant uncertainties in understanding the key processes in the carbon cycle that control the sources and sinks of these gases, which limit the ability to predict their future concentrations. An improved understanding of the Carbon cycle would help to overcome uncertainties that impact the ability to assess radiatively active gases from a comprehensive perspective. Hence, focused research requires improved knowledge of atmospheric lifetimes, global warming potentials, chemical, biological and physical processes that control terrestrial and oceanic sources and sinks, and methods of monitoring emissions. This type of information is essential to develop, implement and determine the effectiveness of response strategies for controlling anthropogenic greenhouse gas emissions or altering the natural carbon cycle, through reforestation or enhanced carbon fixation in oceanic ecosystems.

Ecological Systems and Population Dynamics

The consequences of changes in radiative forcing and climate on biological resources and their dynamics are of critical importance. Human factors (e.g., economics, legal and regulatory systems) influence how these resources are developed and managed throughout the world (see discussion of economics research in the Special Issues section). Humans also cause large scale environmental changes in very direct ways, such as through deforestation, urban expansion and agricultural practices that degrade soils. The study of population dynamics provides links among these interacting social, economic, biological and ecological systems. Some of these links are explicit, e.g., managing food resources; others are inadvertent, e.g., the consequences of urban expansion on wetlands and wildlife habitat or over fishing of fish stocks. However, the ecological, biological, and economic processes that control these impacts are not well understood, and predictions of impacts suffer from great uncertainty. The USGCRP projects encompass both causes and effects of global change, from considering how changes in human populations and consumption patterns affect greenhouse gas emissions, to how rapid changes in climate and atmospheric carbon dioxide may alter the productivity and distributions of naturally regulated plant populations. Studies of population dynamics span spatial scales -- from small-scale experiments on how competing plants may grow in high carbon dioxide atmospheres, to larger-scale considerations of how global food availability may be affected under global change. National and international decision makers, agriculturalists, land managers and the general public must know how global change will affect biological resources, and what can be done to plan for it.

Climate Modeling and Prediction

Table 1 shows that the FY 1992 request for this integrating theme is \$88.5 million, a \$33.8 million or 61.8 percent increase over the FY 1991 enacted level.

Scientific Understanding

Prediction of climate and environmental changes is not straightforward given the complexity of the Earth system and its many feedbacks. For example, the human-generated

increases in atmospheric carbon dioxide concentration is a major factor potentially causing climate change. However, because carbon dioxide is the primary raw material for photosynthesis, increased carbon dioxide concentrations are also likely to have a direct biological affect manifested as changes in the extent and distribution of the Earth's vegetative cover. This, in turn, affects hydrology and surface albedo and could affect climate. Such complex Earth system processes and interactive feedbacks can only be understood through model simulations.

Today's global models simulate with acceptable confidence some of the important processes of global change, such as the direct response of the climate system to increased atmospheric concentrations of greenhouse gases (i.e., tropospheric warming and stratospheric cooling). Many physical processes, however, are treated only in a rudimentary fashion by the models (cloud-radiation interactions, ocean circulation, changes in the distribution and abundance of biota, biologically modulated elemental cycling, and ocean and terrestrial exchanges with the atmosphere of heat, water, carbon dioxide and other gases).

Today, scientists model individual components or limited subsystems of climate, such as the atmosphere; the atmosphere and ocean; or the atmosphere, ocean and prescribed land-surface, rather than the entire coupled system. More reliable climate change predictions, especially at the regional scale, will require representation of the integrated behavior of the climate system with fully coupled subsystem models.

The primary climate models, called general circulation models (GCMs), predict a variety of climatic variables, such as temperature, precipitation, winds, snow accumulation, and soil moisture. Of the possible global climate models in use, only the GCMs provide geographical distributions of these variables and hence, regional predictions. To be used for global change predictions, atmospheric GCMs must be integrated with models of the ocean and land surface and the biotic changes inherent to them.

Research Needs

Observations of a wide variety of past and present physical, geological, chemical, and biological parameters associated with the atmosphere, land, and ocean will be required to improve scientific understanding of how the Earth functions as a single coupled system. Good data and information management are essential to accomplish this. Data sets must be organized and assimilated so the model simulations of present and past environments can be compared to nature as a test of model accuracy.

Model development requires greater understanding of processes within each component of the Earth system (e.g., cloud-radiation interactions) and of processes that involve interactions between two or more of the components (e.g., the roles of the oceans and terrestrial biota as sinks for atmospheric carbon dioxide) and changes that may occur in these processes under different climatic regimes. These processes cut across virtually every scientific element within the USGCRP.

Improving the certainty of climate change predictions at both global and regional scales arising from either natural variations in the Earth's climate system or in response to assumed anthropogenic greenhouse gas emissions scenarios will require significant new computational capabilities. Estimated needs require a thousand-fold increase in computer time. The USGCRP will seek new technology and techniques to enhance computational capability for the USGCRP, both through the Program and through linkages to other programs and initiatives, such as the Federal High Performance Computing Programs.

FY 1992 Research

To achieve the USGCRP's objective of developing a predictive capability for the Earth as an coupled system, the Program's activities of observations, data management, and understanding must all contribute to model development, documentation, testing, application and verification. The proposed USGCRP is structured to accomplish this. In FY 1992, the Program requests \$88.5 million to support predictive climate modeling activities across all of the science elements. Highest priority will be associated with the Climate and Hydrologic Systems, Biogeochemical Dynamics, Ecological Systems and Dynamics, and Earth System History science elements.

Included is a strong and focused multi-agency program for the development, application, and validation of global predictive models of climate change. It is a complementary and coordinated (DOE, NASA, NOAA, NSF, DOI, and USDA) research effort, which:

- highlights research on data assimilation and production of GCM-assimilated climate data sets for model development and evaluation, and for preparing for future EOS data streams.
- centers on improved process representation (parameterizations) and regional resolution and the separation of natural climate changes from those associated with human activities.
- focuses on the development of advanced computational methodologies and capabilities for integrated climate models of the future.
- emphasizes integration of subsystem models (atmospheric, oceanic, and land-surface) to build the coupled climate models of the future.
- focuses on reconstructing and simulating past global change by producing and integrating paleoclimate time series from many sources into a single, usable global database accessible to modelers.

Global Water and Energy Cycles, including Sea Level Change

Table 1 shows that the FY 1992 request for this integrating theme is \$527.1 million, a \$106.9 million or 25.4 percent increase over the FY 1991 enacted level.

Scientific Understanding

The energetics of the atmosphere are strongly influenced by the presence of all three phases of water in the atmosphere. Of significance are interactions between radiation and water vapor (the most important greenhouse gas), the transport and convergence of water vapor in the atmosphere, and the formation of clouds. Clouds play a special role because they are critically important in both energy and moisture exchange. Scientific understanding of these processes is held back by inadequate knowledge of how water in the atmosphere, forced to condense, is organized into clouds of varying type and spatial distribution.

The oceans are by far the dominant reservoir on the planet for both water and heat. Evaporation and precipitation over the ocean result in the exchange of latent heat, as well as water, with the atmosphere. In turn, precipitation and evaporation exert a strong control on salinity, water mass formation, and the deep circulation of the ocean. A prominent example of the interaction of

the upper ocean and the atmosphere is provided by the El Nino/Southern Oscillation (ENSO). Major shifts in upper ocean and atmospheric circulation in the tropical Pacific result in global changes in the distribution of precipitation on interannual time scales. On time scales of decades to centuries, considerably longer than ENSO, paleoclimate studies and coupled ocean-atmosphere models suggest large scale alterations in the north-south distribution of precipitation associated with variation in the deep circulation of the ocean.

Recent research has also shown the importance of land surface processes as modulators of the supply of heat and moisture available in air masses as they move across continents. Although the basic processes that govern the movement of water, from precipitation, infiltration through the soil, ground water recharge and river runoff are reasonably well understood over small areas, they are poorly understood over larger regions and continental-sized areas. It is well known that soil moisture provides a source of atmospheric water vapor that can then produce precipitation. Thus a large area of wet soils can enhance precipitation, while a drought (and the associated dry soils) can become self sustaining. Therefore, terrestrial ecosystems play an important part in these land surface processes.

In response to global warming, future absolute sea level is expected to rise as glaciers melt and seawater expands in volume. During the past century (in response to a global climate warming interval), it is estimated that absolute sea level has risen about 20 cm from the observed worldwide retreat and melting associated with negative mass balances of temperate glaciers, especially those in southeastern Alaska, and from thermal expansion of the oceans. Because of the problems associated with analyses of tide-gauge data (poor geographic distribution of tide gauge sites, inadequate length of records, unstable geologic settings, etc.), it is difficult to extract meaningful information from them. Sea level measured by a tide gauge which is not tied to an external geodetic reference system will only provide measurements of relative sea level, from which it may be difficult or impossible to determine absolute sea level. Coastal regions may be undergoing tectonic uplift or downfaulting, undergoing compaction of deltaic sediments, or still being subjected to crustal rebound following unloading of an ice sheet.

There are enormous uncertainties associated with the sea level question because of the complex interrelationships between: carbon dioxide concentration and temperature of the Earth's atmosphere; cyclical, long-term variations in seasonal hemispheric insolation and global climate; glacier mass balance and climate; rate and magnitude of the exchange between glacier ice and ocean reservoirs; rate and magnitude of thermal expansion of the oceans; and the difficulty of accurately measuring absolute changes in sea level from tide gauges.

Research Needs

Atmosphere: The capability of minor adjustments in relative humidity distribution to alter the characteristics of clouds and hence alter the radiation balance of the atmosphere remains a critical problem. The nature of the feedback between global warming, clouds and water vapor as a radiatively active gas must be better understood and quantified than at present. The connections between the large scale climate system and a potential redistribution of world-wide cloud and rainfall patterns represents a serious deficiency in the ability to model and predict Earth system behavior.

Ocean: The ocean serves as a major thermal conduit between the tropics and polar regions of the Earth. Many oceanic processes critical to problems of long-term change are affected fundamentally by exchange of energy and latent heat (water) across the air/sea interface. Much of the deep circulation of the ocean is strongly determined by patterns of precipitation, evaporation and surface runoff, and the transport of sea ice by surface winds. The cycling of energy and water in the earth system as a "complete" problem requires a thorough understanding of these related oceanic processes.

Land Surface: The hydrology of the land surface is an exceedingly complex system to understand and model. The conservation of water and energy associated with the interactions of atmospheric phenomena such as precipitation and wind, with terrestrial hydrology through fluxes of heat and moisture represent critical constraints in understanding and modeling Earth system behavior. Realistic models of the land surface component of the climate system are dependent upon the development of improved characterizations of local-scale processes and interactions at regional and broader scales. In particular, there is a significant need for improved understanding of (1) evapotranspiration from diverse vegetation, lakes, and other land cover types; (2) infiltration of water through the unsaturated zone and aquifer recharge; (3) the conversion of precipitation to stream flow, including the role of topography at a variety of storm and catchment scales; (4) the processes of snow accumulation, transformation, redistribution, melting, and the growth or shrinkage of glaciers at high latitudes or elevations; and (5) the extent and dynamics of permafrost in polar regions.

Sea Level: There needs to be a better understanding of the relationship between carbon dioxide concentrations in the Earth's atmosphere, temperature and global ice volume. Long-term cyclical or secular variations in solar energy reaching the Earth's surface on a seasonal basis and at different latitudes must also be better understood. A better understanding of the relationship of regional and global climates and glacier mass balance is required, especially the present-day mass balance of the different components of the Greenland and Antarctic ice sheets. The rate and magnitude of exchange of water between glacier ice and the oceans during the past 200,000 years is needed. An improved understanding of the rate and magnitude of thermal expansion of the oceans is needed for different warming scenarios. The most important issues regarding sea level are: to determine the contemporary rate of change in global absolute sea level, detect any change in that rate with time, identify the ice mass changes associated with observed changes in sea level, and estimate the expected change in sea level during the next decade to century.

Modeling: Representation of the hydrologic cycle is one of the major acknowledged weaknesses in climate general circulation models. For example, in several coupled climate models, errors in the flux of water between ocean and atmosphere result in anomalous distributions of sea surface salinity and ultimately, unrealistic model results. While flux correction routines are used to counteract the growth of such errors, better model representation of the movement of water on the planet is the ultimate answer. On smaller space and time scales, projections of regional drought using numerical models appears within reach using extensions of existing weather prediction approaches. Scaling issues also dominate the challenge of modeling the terrestrial biological component of the hydrologic cycle.

FY 1992 Research

A range of ongoing research programs, augmentations and new initiatives of the USGCRP will each contribute to different aspects of the required research. The agency programs are listed in a table in the Appendix, along with their FY 1991 enacted and FY 1992 requested budgets. FY 1992 programs will specifically include:

Atmosphere: Substantial ongoing and new research programs are focused on this area. Ongoing activities include the NASA, NOAA, NSF International Satellite Cloud Climatology Project (ISCCP); the NASA Earth Radiation Budget Experiment (ERBE); the NOAA Global Precipitation Climatology Project (GPCP); estimates of clouds and radiation from geostationary and polar-orbiting satellites (NOAA); the Global Energy and Water Cycle Experiment (GEWEX: NOAA, NASA, NSF, and DOI), which will address the processes controlling the distribution of water and energy on the planet; DOE's Atmospheric Radiation Measurement (ARM) program, which will focus on extensive ground-based measurements of clouds and radiation; and NASA's

EOS mission, which will provide the larger scale perspective from space. DOE's Quantitative Links program examines the relationships between atmospheric composition and global climate change, is another continuing program. New activities this year include NSF's Role of Clouds program, targeted specifically towards quantifying the radiative effects of clouds on a global scale. The Greenland Ice Sheet Program (GISP), a component of NSF's Arctic System Science (ARCSS) initiative, will produce new data concerning paleoclimate. Funding is also requested for NASA's Tropical Rainfall Measurement Mission (TRMM), a critical expansion of efforts to quantify precipitation in lower latitudes.

Ocean: The overall USGCRP effort in this area consists of a broad examination of the general circulation of the ocean and basin-scale studies of particular modes of ocean-atmosphere interaction, together with the building of an upper ocean observing system to quantify air-sea fluxes on a continuing basis. The World Ocean Circulation Experiment (WOCE: NSF, NOAA, NASA, ONR and DOE) is a measurement and modeling program of the circulation of the global ocean. The Tropical Ocean-Global Atmosphere Program ([TOGA]: NOAA, NSF, and NASA) has provided major advances in the understanding of interannual climate change, particularly its interactions with the tropical Pacific. Another basin-scale study, the NOAA Atlantic Climate Change Program aims at examining the interactions between the Atlantic and global climate. In situ ocean observation systems (NOAA, NSF, DOI and DOD) will contribute to studies of ocean circulation and the coupling of the ocean and the atmosphere, while the new generation of space-based measurements of ocean altimetry, temperature, and wind stress (NASA EOS, ADEOS, TOPEX/Poseidon) will provide the global context to these observations. Prior to EOS, a critical global data set for hydrologic cycle issues will be provided by the NASA Scatterometer, since wind stress measurements over the oceans will be critical to estimating the air-sea fluxes of heat and momentum. Several agencies (NSF, NOAA, DOI, SI, and DOD) will conduct paleoceanographic studies to provide improved documentation and understanding of past changes in deepwater formation and circulation, including possible abrupt mode shifts such as the Younger Dryas; and past changes in sea-surface temperatures as well as changes in patterns and intensity of surface currents.

Land Surface: A central problem in land surface hydrology involves relating local scale hydrologic processes to those at regional, continental and global scales. Coupling spatially detailed hydrologic models with spatially coarse general circulation models requires the development of a new class of models that can bridge the gap between the catchment and GCM grid scales, as well as improved understanding of hydrologic processes in large basins. A number of agencies are proposing modeling activities and basin studies to address this requirement, including DOI (Interaction of Climate and Hydrologic Systems, Regional Studies, Sensitivity of Hydrologic Systems, Sensitivity of Water Resources), DOD (Coupled Hydrologic/Thermal Basin Modeling), and USDA (Scale Effects of Hydrologic Processes). Basic representation of landscape attributes will be provided by the Land Characterization program of DOI. Support for basic research on processes such as groundwater and reservoir recharge will be provided by the NSF Continental Hydrologic Processes program. NSF will also support the planning and development of the Water-Energy-Vegetation (WEV) project, which focuses on interactions between vegetation and the physical environment, specifically water and energy. Integration for many of these projects will be provided by the Global Energy and Water Cycle Experiment (GEWEX) program, which will initiate a continental scale study in North America. Lastly, the global observational context for these land surface studies will be provided by the EOS platform. In addition, there will be a significant expansion of research in polar regions in FY 1992. The NSF Arctic System Science program will initiate coordinated interdisciplinary investigations of Arctic ocean-ice-atmosphere interactions, while the DOI Cold Regions Research program will be directed toward understanding changes in glaciers, permafrost, snow cover, and floating ice. Paleocological studies in NSF, DOI, USDA, and SI will provide information on changes in vegetation associated with past climate changes.

Sea Level: After evaluating national and international policy needs, scientific background, and required understanding, a responsive multi-disciplinary research effort was developed. Increased effort in ongoing projects and several new projects are focused on sea level during FY 1992. These include the following programs: increased deployment for the Global Sea Level Monitoring Network (NOAA); ice sheet observations (DOI and NASA); monitoring of glacier mass balance (DOI); general circulation modeling related to sea level change (DOE, NASA, NSF, and NOAA); and crustal motions and sea level (NASA, NOAA, and NSF). Considerable research will contribute to understanding past variations in sea level, including: paleo-atmospheric carbon dioxide abundances (DOE, NSF, and DOI); the second Greenland Ice Sheet Project (GISP II) which will recover data in ice cores from Greenland (150,000-year record)(NSF); high-resolution paleoclimatic records (DOI, NSF, and NOAA) containing several centuries of records preserved in corals, ice-cores, and varved sediments; the Abrupt Climate Change program of NSF; and the reconstruction of sea level history and its relationship to climate change (DOI). The impacts of sea level change will be addressed under two programs: Models of Human Interactions in Global Change (NSF); and Coastal Erosion, Inundation, and Wetlands Loss (NASA, DOI, and NSF).

Modeling: As described in the Modeling and Prediction Integrating Theme, a complementary interagency (DOE, NASA, NOAA, NSF, and DOI) program for the development and application of predictive models of climate change is proposed for FY 1992, with a strong emphasis on hydrologic cycle issues. It emphasizes the integration of subsystem models (atmospheric, oceanic and land surface) to build the coupled climate models necessary for more certain predictions of climate change; it highlights the development of advanced computational methodologies and capabilities for integrated climate models of the future; it focuses on improved process representation and regional resolution and the separation of natural climate changes from those associated with human activities; and it includes research and production of GCM-assimilated climate data sets for model development and evaluation, and for preparing for future EOS data streams.

Global Carbon Cycle

Table 1 shows that the FY 1992 request for this integrating theme is \$165.0 million, a \$33.1 million or 25.1 percent increase over the FY 1991 enacted level.

Scientific Understanding

Working Group 1 of the IPCC highlighted the need for an improved understanding of the sources and sinks of radiatively and chemically active atmospheric gases, their chemical reactions in the atmosphere, and how they may be influenced by climate change.

Carbon Dioxide: The concentration of atmospheric carbon dioxide is now about 350 parts per million (ppm) (1989), and is increasing about 1.8 ppm per year. The challenge in carbon cycle research is to understand the fate of the "new" anthropogenic carbon (about 6 billion metric tons of carbon as carbon dioxide) released annually from human activities. Although very small in comparison to the natural fluxes, human-influenced fluxes have been large enough to increase atmospheric carbon dioxide concentrations by 25% since pre-industrial times. Indirect evidence suggests that the land and oceans may sequester anthropogenic carbon dioxide in roughly equal proportions (about 2 billion metric tons each per year), although the mechanisms are not well understood. Recent models suggest that the most significant land or ocean sinks may be in the northern hemisphere.

The rate of carbon dioxide uptake by the oceans is controlled by both the exchange rate at the sea-air interface and the chemical, biological, and physical processes that transfer carbon-containing surface water to the deep ocean and sediments, where it is sequestered for long periods.

There are suggestions that human influenced sources of nutrients may be increasing productivity in near-shore and/or oceanic ecosystems. Several possible mechanisms have been suggested for enhanced sequestration of carbon by terrestrial ecosystems: (i) enhanced productivity under warmer conditions, (ii) direct effect of enhanced photosynthesis due to increased atmospheric carbon dioxide and enhanced deposition of nitrogen compounds, and (iii) land management practices that may have sequestered additional carbon in terrestrial ecosystems.

Methane: The current atmospheric methane concentration is 1.72 ppm, more than double the pre-industrial value, is increasing at a rate of 0.9% per year, and is greater today than at any time during the last 160,000 years. Methane is produced from a wide variety of anaerobic sources. Important sources of methane include natural wetlands (tropical and high latitude peatlands), rice cultivation, enteric fermentation in animals, biomass burning, methane clathrates, and natural gas venting. Less well known are the environmental, physical, geological, chemical and biological processes that control the releases of methane to the atmosphere. Hence, a key requirement in understanding atmospheric methane is to quantify the fluxes of methane from different sources, and to identify and understand the processes that control these fluxes and their sensitivities to climate change.

Oxidation in the troposphere is the major sink for atmospheric methane, and results in an atmospheric lifetime of about 10 years. Photochemical models currently suggest that the atmospheric oxidizing capacity may be declining, which would imply a longer residence time for methane. However, while the knowledge of the sources and sinks of atmospheric oxidants has improved over the past decade, it is still incomplete. The natural sources of tropospheric oxidants are downwelling of ozone from the stratosphere and photochemical reactions involving nitrogen oxides, carbon monoxide, methane, and non-methane hydrocarbons, which have both natural and man-made sources. There is now evidence to suggest that, during the past century, oxidant (primarily ozone) levels in industrialized and remote areas in the northern hemisphere areas have increased due to growing abundances of the above pollutant precursors.

Research Needs

Understanding the carbon cycle requires scientific information spanning numerous scientific disciplines and all seven scientific elements and three scientific objectives of the U.S. Global Change Research Program. The scientific needs can best be described within the following framework:

Atmospheric Carbon: Reconstruct historic and monitor contemporary atmospheric distributions and trends of carbon dioxide and methane, including their isotopic composition. Identify and understand the atmospheric processes responsible for removal of methane isotopes in an effort to more accurately quantify sources. Additionally, it is important to investigate, through laboratory and field studies, the atmospheric and physical chemical processes involving ozone, carbon monoxide, nitrogen oxides, and non-methane hydrocarbons that affect atmospheric lifetimes and that control the escape of chemically active compounds from the surface to the global atmosphere.

Oceanic Carbon: Quantify the local, regional, and global fluxes of carbon dioxide (including isotopic composition) between the atmosphere and oceans and understand the ecological, biogeochemical, and physical processes (a) that control the fluxes of carbon dioxide between the atmosphere and ocean surfaces, (b) that are responsible for the exchange of carbon between the land, ocean margins, surface waters, deep ocean waters, and sediments, (c) that control the cycling and transformation of carbon within the oceans (between dissolved and particulate inorganic and organic carbon compounds); and (d) that may respond to changing environmental conditions (e.g., ocean temperature, ocean circulation, air-sea exchange rates, etc.).

Terrestrial Carbon: Quantify the local, regional, and global fluxes of carbon dioxide, methane, carbon monoxide, and non-methane hydrocarbons (including their isotopic composition) between the atmosphere and a wide range of natural and managed terrestrial ecosystems and understand the ecological, biogeochemical and physical processes that control the (a) fluxes and isotopic composition of these carbon gases between the atmosphere and the terrestrial biosphere and (b) amount of carbon stored in different terrestrial ecosystems and their structural components (e.g., live biomass, detritus, soil, permafrost, and sediments), and (d) cycling and transformation of carbon within the terrestrial biosphere. It is particularly important to understand the impact of changing climate conditions, the effect of increased carbon dioxide, the frequency of fires, and chemical deposition on growth and carbon fixation by vegetation.

Human Dimensions of the Carbon Cycle: Identify patterns of change in anthropogenic sources and sinks at local, regional, and global scale. This will involve determining the influence of 1) economic and population forces in these changes, 2) the relationships among fluxes in carbon dioxide and methane and changing patterns of land use and food production, marketing, and consumption; 3) the relationship among economics, industry, transportation, and local, regional, and global fluxes of carbon dioxide, methane, carbon monoxide, and non-methane hydrocarbons, e.g., carbon dioxide from the combustion of fossil fuels (see Economics Research under Special Issues section).

Global Carbon Models: Develop global carbon models to synthesize the understanding of the processes that control the distribution and partitioning of carbon within the atmosphere, oceans, and terrestrial ecosystems, and the fluxes among them. Such models should ultimately comprise an atmospheric model of carbon dioxide circulation and photochemical carbon processes, an oceanic circulation model incorporating chemical, biological and physical processes, and terrestrial models of carbon cycling in ecosystems and carbon dioxide exchange with the atmosphere. Tested models will simulate the atmosphere-ocean-terrestrial exchange processes, and will be used to predict future concentration of carbon dioxide and methane in relation to altered human and natural sources and sinks.

FY 1992 Research

Ongoing research programs, augmentations and new initiatives of the U.S. Global Change Research Program each contribute to different aspects of the required research. The agency programs are listed in a table in the Appendix, along with their FY 1991 enacted and FY 1992 requested budgets. FY 1992 programs will specifically include:

Atmospheric Carbon: DOE and NOAA will continue to monitor the temporal and spatial distribution of atmospheric carbon dioxide, including its isotopic composition. NOAA will expand its monitoring, including additional sites and vertical profiles at selected sites. NSF and DOI will utilize glacier ice core and tree ring data to document past changes in atmospheric carbon dioxide. DOI will monitor carbon dioxide emissions from volcanoes. NASA and NOAA will utilize intercalibrated in situ measurements from networks of ground-based stations and regular aircraft flights to establish the global abundance of methane and its change with time. Measurements of methane will be complemented by a limited number of isotopic composition studies of contemporary atmospheric methane, and methane trapped in glacier ice cores (NASA and NSF). The NOAA baseline observatories will begin regular measurements of carbon monoxide. Instruments are being developed under NASA's EOS program, which will begin mapping global vertical distributions in the troposphere of methane and carbon monoxide and estimate column amounts of a large number of other constituents late in the decade.

NASA, NOAA, NSF, DOE, and EPA will perform laboratory kinetics studies, conduct

field measurements, and carry out diagnostic modeling to improve our understanding of the atmospheric cycling, distribution and transformations of ozone, hydroxyl radical, nitrogen oxides, carbon monoxide, and non-methane hydrocarbons that control the distribution and lifetime of methane. NOAA will emphasize understanding the isotopically-dependent processes that remove methane. Field measurements will be done as part of process-oriented studies in remote regions, such as NASA's Global Tropospheric Experiment (GTE) in the tropics (Brazil), northern wetlands (Canada), and the eastern Pacific. The focus will be airborne campaigns aimed at the processes occurring in the tropical Atlantic and western Pacific, and boundary-layer/free-troposphere studies in the continental U.S. and Atlantic. The NSF, NOAA, and DOE studies will continue to use Mauna Loa as a remote-area site. Such studies will also include the International Global Atmospheric Chemistry (IGAC) projects in the northern Atlantic, which is a region perturbed by man-made emissions (NOAA and NSF).

Oceanic Carbon: NSF, NOAA, DOE, and NASA are all active participants in the international Joint Global Ocean Flux Study (JGOFS), a core project of the IGBP, whose goals include understanding the transport and transformations of carbon and other biogenically important elements within the ocean and a quantification of the atmosphere - ocean exchange of carbon dioxide, hence understanding the role of the oceans in controlling the build-up of carbon dioxide in the atmosphere. NSF, NOAA and DOE will expand measurements of ocean carbon chemistry, including in situ studies of the chemical, geological, biological and physical processes responsible for controlling the distribution and exchange of oceanic carbon and other biogenically important elements between the ocean margins, open surface waters, deep oceans, and sediments. NOAA and DOE will utilize networks of automated buoys and ship transects to determine the spatial and temporal concentrations of carbon dioxide in surface waters and to quantify the air-sea fluxes of carbon dioxide. DOD will further refine instrumentation to continuously estimate biological productivity responsible for the fluctuations in oceanic carbon in high latitude surface waters. The data from JGOFS will be complemented by an improved understanding of air-sea exchange processes and ocean circulation processes, particularly the exchange of water between the surface layer and the deep ocean, from the WCRP, WOCE, and TOGA programs, which are actively supported by NSF, NOAA, DOE, and NASA.

NOAA, DOI, and DOD will perform contemporary and paleoceanographic studies utilizing geochemical, isotopic, and paleontologic data to provide an improved understanding of past changes in: (i) deep water formation and circulation, including areas of formation, rates and patterns of flow, and possible abrupt mode shifts such as occurred during the Younger Dryas period; (ii) productivity of surface waters and carbon sequestration in lake, coastal and oceanic sediments; and (iii) sea surface temperature and surface currents.

A number of in situ studies will be complemented in the future by remote sensing measurements from the NASA Earth Probes (Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and Scatterometer (NSCAT)) and EOS missions of ocean biological productivity, sea surface temperatures, and surface winds, which will help characterize carbon dioxide fluxes across the air-sea interface. Launch of Earth Probes is expected about 1994-95, and the EOS missions at the end of the decade.

Terrestrial Carbon: DOI, NSF, EPA, DOE, NASA, and USDA will study, using in situ and remote sensing techniques, the biogeochemical processes responsible for the sequestering and release of carbon dioxide and methane and the storage (soils and vegetation) and cycling of carbon and other key nutrients (e.g., nitrogen and phosphorus) within a large number of diverse natural (boreal and tropical forests, tundra, grasslands, and wetlands) and intensively managed (e.g., commercial forests, rangelands, and agricultural systems) terrestrial ecosystems.

NASA, NOAA, NSF, EPA, DOI, DOE, and USDA will each study the fluxes, as well as the biogeochemical processes controlling them, of methane from one or more key sources, such as

natural terrestrial ecosystems (e.g., tropical and boreal forests, grasslands, and high latitude peatlands), agricultural systems (particularly rice paddies), oceans and freshwater systems, managed forests, domesticated ruminants, termites, biomass burning, land-fills, venting of natural gas, methane hydrates in terrestrial and marine sediments, and coal mining. The emphasis will be on mechanistic studies, so that process and global-scale models can be developed and used to assess current methane sources and predict future changes in these sources.

USDA will measure gaseous emissions from forests under different climatic and disturbance (e.g., deforestation) regimes. NOAA will carry out tower measurements of selected sites, combined with modeling analyses, to estimate regional carbon dioxide sinks. EPA will focus on local ecological and biological processes that control fluxes of carbon and nutrients, primarily in high-latitude ecosystems and secondarily in temperate and tropical ecosystems, e.g., biomass burning.

DOE conducts basic research on direct effects of carbon dioxide on vegetation, including control by carbon dioxide of fundamental biological processes such as photosynthesis, transpiration, and overall growth responses of plants.

Several existing research and monitoring programs will contribute to monitoring storage and movement of carbon and nutrients within ecosystems. DOI will provide relevant data on tundra permafrost melting and release of methane and stored carbon, and will integrate relevant baseline data on natural ecosystems. The USDA will provide biological data relevant to carbon and nutrient storage in terrestrial ecosystems in the U.S., as will continuing observations from NSF's Long-Term Ecological Research (LTER) and Land Margins Ecosystem Research (LMER) networks. USDA will test the hypothesis that the 25% increase in atmospheric carbon dioxide has increased the amount of carbon stored in the soils underlying croplands, pastures, and forests. EPA will assess the ability of tree-root and soil systems to sequester carbon; this ability may be an important physiological control of carbon storage. DOI, USDA, and EPA are developing methods of measuring the movement of carbon compounds within terrestrial systems and from terrestrial to coastal systems. An emphasis will be on the sensitivity to physical parameters, such as water content of soils, and the relation to ecosystem properties and responses.

NSF, NOAA, DOI, SI and USDA will conduct paleoecological studies utilizing geochemical, isotopic, and paleontologic data to understand past rates and magnitudes of uptake and release of carbon through terrestrial systems as monitored by changes in vegetation and environments, and organic content of sediments, including permafrost, and soil development.

DOI, NOAA, DOE, and NASA will utilize existing (Landsat, Advanced Very High Resolution Radiometer - AVHRR, and other) satellite imagery for land-cover classification, vegetation-index analysis, and to estimate changes in land use and the biological productivity of terrestrial ecosystems. Satellite data will be used in conjunction with ground-based and aircraft experiments to scale processes observed at the site level to the regional scale. NASA is developing a complement of surface imagers on EOS to expand this capability, and planned experiments in the International Satellite Land Surface Climatology Project (ISLSCP) will provide improved methodologies. The increased spectral and spatial specificity of NASA EOS instruments - High-Resolution Imaging Spectrometer (HIRIS) and Moderate-Resolution Imaging Spectrometer (MODIS) - for ecosystem studies may provide the capability to monitor changes in nutrient storage from satellite data. ISLSCP is a contemporary program, while EOS measurements are planned to begin late in the decade.

Human Dimensions of the Carbon Cycle: DOE and EPA will be supporting extensive programs of research into human interactions in the carbon cycle (see discussion of economics in the Special Issues section). They will characterize anthropogenic emissions sources and project changes in the rates of emissions over time. DOE and EPA will also support research on the

influence of anthropogenic carbon emissions on climate. DOI will examine supply curves for undiscovered oil and gas. DOE will examine industrial and technological consumption of fossil fuels and predict future consumption under different technologies.

The role of fire and terrestrial vegetation as sources of carbon production will be the focus of research in the USDA. Human interactions in tropical agroforestry and in arctic ecosystems will be examined by the SI and by DOI. NSF will examine social and economic influences on and incentives in carbon production. DOI and NSF will support research on changes in land use.

Global Carbon Models: There are a number of agency activities that will eventually lead to improved global carbon-cycle models. DOE, DOI, EPA, NASA, NSF, and USDA will carry out a broad range of process-oriented and global-scale modeling studies to simulate global terrestrial carbon-cycling processes, including the coupling between the carbon cycle and water and energy fluxes from terrestrial and near-coastal ecosystems. These efforts include the use and the development of diagnostic and prognostic models of global carbon balances, which include the effects of deforestation, the uptake and release of carbon dioxide by terrestrial biota, and how these are influenced by changing climatic and other environmental conditions.

DOI, DOE, NOAA, NASA, and NSF will develop improved ocean carbon models, including satellite data assimilation, some of which will incorporate chemical and biological processes into three dimensional ocean general circulation models. NASA, NOAA, NSF and EPA will develop multi-dimensional tropospheric photochemical models to determine the atmospheric lifetimes of methane and carbon monoxide, and to evaluate how changes in trace gas emissions will affect the chemical composition of the troposphere, and hence atmospheric lifetimes. NSF and DOI will develop models to simulate observed variability in paleocarbon records.

Ecological Systems and Population Dynamics

Table 1 shows that the FY 1992 request for this integrating theme is \$147.0 million, a \$41.0 million or 38.7 percent increase over the FY 1991 enacted level.

Scientific Understanding

Current scientific knowledge positions the USGCRP well to undertake major research efforts in population dynamics. In both methodological and substantive areas, the USGCRP will be building on a secure and well-founded base of knowledge in five major areas.

Sampling, Monitoring, and Database Development: In situ methods for sampling human and terrestrial biological populations are more advanced than for aquatic populations. Crop yields, fishery and forestry resources, and the abundances of game and some non-game species are measured routinely by Federal, local and state governments in many nations and by international organizations. Indices of distribution of major plant life-forms (but not individual species) and ocean color can be made from space, (e.g., from AVHRR and Coastal Zone Color Scanner (CZCS) data). Sampling statistics are extremely well developed in both the social and natural sciences, and surveys are routinely conducted on samples of human populations. Databases are less well developed.

Dynamics of Growth and Decline: The sensitivities of populations to global change depend on several factors, including the health of the individuals, their absolute numbers, their location relative to their natural environmental range, the existence of competitors and/or predators and pests, and the existence of keystone species. Adaptation to natural disturbances (i.e., hurricanes and fire) also influence species distributions and abundances. The nature and rate of growth in human populations are well understood. The influence of society, economics, and legal inputs and

practices on human populations is less well understood, but has been the topic of extensive theoretical and empirical research. Interactions between human and natural populations determine many biological responses, i.e., the loss of species as a result of habitat loss following urbanization.

Resource Accounting: The concepts of managing and accounting of individual resources have been well studied. The enterprises of agriculture, forestry, wildlife management, fisheries management, etc. all depend on basic knowledge of how the target populations respond to harvesting and hunting. The basic economic concepts for describing the payoffs and costs of these activities are also known, and in some cases (i.e., agriculture) the descriptions of market economics and biological response have been combined.

Prediction of Threshold Responses: Populations may collapse after reaching critically low or high numbers, or if important habitat or food resources are removed. Paleoecological data demonstrate that different combinations of species can be expected in different climatic regimes. Human populations and their institutions also show both continuous and discontinuous responses to environmental stresses. Environmental deterioration may have significant physiological effects on human populations.

Modeling: The scientific community has many well-developed tools for simulating the dynamics of single, and in some cases two or more interacting populations of plants and animals. Demographic models of human populations are well understood, and the interactions between economic behavior and the abundance and distribution of natural resources can be modeled on a resource-by-resource (i.e., individual crops) basis.

Research Needs

In order to advance the state of knowledge in critical areas of global change and population dynamics, the USGCRP has identified gaps in each of the areas of knowledge outlined above.

Sampling, Monitoring, and Database Development: While methodological issues do not require much attention, except in marine systems, the application of sampling and monitoring methods needs to be extended over longer periods of time for both natural and human populations. Only with longer time series of data will scientists be able to detect the projected changes due to global change over a naturally variable background of change. The empirical climate record and general circulation models have made obvious the lack of detailed ecological databases with comparable data.

Dynamics of Growth and Decline: Four key unknowns in natural environments are (a) to what extent do climatic averages and variability, as well as carbon dioxide concentrations, control species composition and abundances, (b) to what degree do interspecific interactions determine the composition of the assemblage, (c) which species are the most important in any particular assemblage of species, and (d) how are species interactions likely to be altered under global change? In human-impacted environments, more understanding is needed of the consequences that global change will have on human health and on the vulnerabilities of economic institutions nationally, regionally, and worldwide. The consequences of global change for geographic distributions, dispersal and migration of populations, both human and otherwise, are poorly understood.

Resource Accounting: A more realistic accounting of the true environmental and economic costs of resource exploitation and management is necessary for wise stewardship of resources now and in the future. Better descriptions and models of the links between energy use, agricultural and forest management practices, land-use, human migration and gas emissions will be especially

important for predicting both direct and indirect human contributions to global change.

Prediction of Threshold Responses: Greater understanding is needed of the concepts of thresholds in both economic and ecological systems. Biological and human populations susceptible to irreversible outcomes should be identified. The processes that lead to rapid changes in abundance or distribution, such as forest diebacks or fish population collapse, must be studied in relation to global change.

Modeling: Biological models of several interacting populations must be improved, coupled to the physical environment, and scaled up to larger geographic regions. Human population and economic models should be integrated with resource and biological models, in order to provide a more complete description of the interaction of resource management and the distribution and abundance of species. Simulation models must improve from being primarily descriptive to having quantitative predictive power. Analytic models must turn their attention to investigating the impacts of global change on assemblages of species.

FY 1992 Research

The Agencies in the USGCRP have proposed a broad attack on these research needs. The Federal activities proposed for FY 1992 are summarized below, and a table in the Appendix delineates each Agency's FY 1992 projects.

Sampling, Monitoring, and Database Development: Using remotely-sensed data from Landsat, AVHRR, CZCS, Scanning Multichannel Microwave Radiometer (SMMR), and Special Sensor Microwave/Imager (SSM/I), NASA and NOAA are providing synoptic observations of many of the world's terrestrial and marine ecosystems. DOI and other agencies are using these observations to document current ecosystem state, surface-cover type, and usage patterns. These observational programs are enhanced by EPA and NASA research that provides quantified methods to analyze these data for land use and cover on continental scales. EOS will continue the satellite record (i.e., MODIS), providing a 15-year continuous record of observations of change over time and intrinsic ecosystem variability.

Several agencies are making ground-based, direct long-term observations of ecological phenomena, documenting natural variation and changes in rate or amplitude of that variation. In a variety of remote areas that are substantially free of human influences, DOI is conducting longer-term, baseline observations. NSF's LTER Program supports long-term studies of natural populations over appropriate temporal and spatial scales to provide the basis for understanding changes in population abundance, distribution and occurrence of local and regional extinctions. NSF (Global Ocean Ecosystems Dynamics (GLOBEC) and LMER) and NOAA (Marine Ecosystem Response Program) will provide an understanding of the natural variability of marine populations. Long-term data from DOE environmental research parks provide a basis for assessing changes and separating them from changes resulting from human influences. The USDA is providing long-term monitoring of the productivity, health and diversity of agriculture, forest and range ecosystems, and DOI is conducting long-term monitoring of selected fish and wildlife species. DOI is comparing selected ecosystems at different elevations and latitudes at varying climatic extremes to provide understanding of the ability of natural and managed systems to adjust to changes in their climatic constraints. The SI will focus primarily on tropical forest and marine ecosystems.

USDA, NSF, DOI and EPA will gather data related to population size, distribution, and land-use. The same agencies will acquire information on economic activities, including the human factors in the use of natural resources and emission of gases and other substances by industries. NSF will support basic research projects that generate data on related topics. DOI will investigate

the effect of global change on ecosystem use by native societies.

Dynamics of Growth and Decline: NSF, USDA, DOI, DOE, the SI and EPA are all conducting physiological studies of individual plant and animal response to climatic variability. These studies, which use both laboratory and field-based experimentation and observations, evaluate the physiological sensitivity of species to climate change. NSF (GLOBEC) and NOAA are developing mechanistic understanding of the processes determining the variability of marine animal populations in space and time, in particular the physiological and genetic responses of marine populations and species to change, and the interaction of population dynamics and the dynamics of ocean physics at micro- to basin-scale. Both climatic stresses and physiological stress from increased UV-B flux are being investigated by EPA, USDA, DOI, and NOAA. NSF, NOAA, DOI, USDA, DOE, and the SI provide badly needed data on the natural histories and population dynamics of plant and animal species. Paleoecological studies by DOI and the SI will provide critical long-term historical information.

On population and community scales, NSF (Ecological Rates of Change (EROC)) and NOAA will focus on the roles of ecological and biological interactions, such as competition, predation, parasitism, and pollination in determining the character of species' assemblages and rates of population changes under future conditions of global change. DOI will examine the spatial and temporal changes of species assemblages in ecotones, relict communities, and along altitudinal gradients. USDA will focus on determining changes in the occurrence and intensity of fires and disease outbreak. Additionally, NSF, NOAA, DOI and USDA programs will investigate how species interact competitively and in predator-prey relationships.

NSF will sponsor fundamental research projects that analyze factors that influence human population dynamics, e.g., rapidly changing economic and environmental conditions that affect migration. Ongoing coastal-resource research and management activities in NOAA and NSF will improve the understanding of the effects of changing populations in coastal regions. USDA will conduct research on the ways in which population-location decisions affect patterns of local and regional resource use and will identify the potential demographic effects of changing global environmental conditions. NSF will sponsor analyses of the ways in which rapidly expanding populations are altering environmentally sensitive zones in the U.S. and elsewhere.

At a landscape scale, terrestrial disturbances (e.g., fire and windthrow) will be studied by USDA, DOE, DOI, and NSF programs. NSF will focus on the roles of ecological and biological interactions, such as competition, predation, and parasitism in determining the character of species' assemblages under future conditions of global change. USDA and DOE will concentrate on the influence of fire and pathogens. DOI will conduct studies on the linkages between terrestrial and aquatic community dynamics at this level.

Resource Accounting: NSF and other agencies will plan and conduct pilot analyses in order to move toward establishment of a set of Long-Term Regional Research Sites (LTRR's) at which both standardized and site-specific data on human activities and related natural environmental conditions will be gathered at several spatial scales. DOI will provide land-use, geologic and hydrologic data. NOAA will provide population data and, in coastal settings, hydrologic and land-use data, and USDA will provide data on soils and agricultural practices, as well as sponsoring work on the development of international measures of agricultural production practices, production levels, input levels and prices. USDA will provide data for forest resources from their experimental forests, Forest Inventory Assessments and the Forest Health Monitoring Program.

NSF will give special attention to comparative analyses of risk-assessment and decision-making procedures in different types of institutions and the determination of means whereby intangible costs and benefits may be more effectively integrated into decision-making procedures.

DOI will study how institutions make trade-offs among social, economic, and environmental goals and how those trade-offs affect resource management strategies.

USDA and DOI will reconstruct data on historical land-use patterns, forest and vegetative cover, agricultural production levels and practices, and human settlement forms, in addition to monitoring. DOI, NSF, USDA and NOAA will all analyze the impacts of different management practices on water flow and quality. DOE will develop improved characterizations of the human factors in energy technology, energy resources, and the potential savings for technological developments and conservation by energy users.

Prediction of Threshold Responses: NSF, DOI, the SI, and EPA will investigate the processes contributing to species diversity and the responses of species to habitat fragmentation and/or loss as a function of global change. GLOBEC will focus on coupled physical-biological models with three themes: conceptual studies of simplification and predictability, site specific models prior to field programs, and the influence of idealized flows on processes. USDA will enhance its fire and disturbance studies in order to better predict species response under global change.

Modeling: On landscape-to-global scales, NSF, USDA, DOE, and NASA will develop nested, hierarchical models of ecological systems. Process models will be integrated into Geographic Information Systems (GIS) and then compared. As an additional method, NSF and EPA are constructing and testing rule-based and response-surface models, which derive possible system sensitivities and rates and types of population response to global change.

USDA will develop models to evaluate the relationships among global agricultural production, new agricultural technologies, international trade, sectoral competitiveness, and the changing global environment. EPA will continue to analyze emissions-forecasting models to provide better estimates of how various economic, technological, societal, and resource-use conditions influence future emissions.

DOE will model interactions of the production and use of energy with other elements of the economy. EPA's contribution will be to investigate the human factors that influence the extent and magnitude of biomass burning and anthropogenic methane emissions.

Other Research Activities

Table 1 shows the FY 1992 request for USGCRP activities that fall outside the four Integrating Themes. The FY 1992 request of \$257.9 million includes an increase of \$16.5 million or 6.8 percent over FY 1991 enacted resources for these activities.

While the Integrating Themes provided a principal focus for major funding enhancements, the President's FY 1992 Budget also includes resources to maintain programmatic momentum in a number of other critical USGCRP activities. These include support for investigations in the areas of stratospheric ozone; biodiversity; human interactions; solid Earth processes; and solar influences.

Stratospheric Ozone

Policy Relevance: The discovery of the Antarctic ozone "hole" in 1985 and the intensive research efforts during 1986-1989 to discern its cause have attracted the attention of scientists, national and international policymakers, and the public. While unfolding a little too late to influence directly the 1987 United Nation's (U.N.) Montreal Protocol on Substances that Deplete

the Ozone Layer, the results of this research strongly shaped the June 1990 amendments to the Protocol. The possible implications of the scientific questions that this newly-discovered phenomenon pose will echo in future policy debates about (i) the degree and timing of additional controls on emissions of chlorofluorocarbon (CFC) substitutes and (ii) the impacts of future ozone losses on polar regions and global climate.

Research Needs and FY 1992 Program: An improved understanding of the hemispheric and global consequences of stratospheric ozone depletion in the polar regions requires studies of: (i) the photochemical reactivity and spectroscopic properties of stratospheric gases; (ii) the distributions and trends of source gases in the troposphere; (iii) trends in the physical structure and chemical composition of the stratosphere; (iv) the interplay between chemical, dynamical, and radiative processes in the stratosphere; and (v) new instrumental techniques.

In FY 1992, NASA and NOAA will expand the Network for Detection of Stratospheric Change (NDSC) which is providing ground-based measurements of ozone and ozone-related species that are perturbed by human activities and which serves as the ground-truth and independent calibration for satellite data. The NDSC station at Mauna Loa will be completed and instruments will begin operation there and at other worldwide sites. Field campaigns and laboratory research in FY 1992 will examine how physical and chemical transformation and transport processes affect ozone losses in both polar and mid-latitude regions (NOAA, NASA, NSF, and EPA). Particular emphasis will be placed on an Arctic campaign, to be conducted in collaboration with European research activities, and in preparation for a similar campaign near Antarctica. NASA will launch the Upper Atmosphere Research Satellite (UARS) in early FY 1992 to study the coupling between the chemical, dynamical and radiative processes that control the abundance and distribution of stratospheric ozone. EPA will also continue studies related to the human health impacts of ozone depletion.

Biodiversity

Policy Relevance: Understanding global change requires understanding and predicting the dynamics of ecological systems, including their biological diversity. Ecological systems form a link between the physical and biogeochemical aspects of the global climate system and the influence of humans on the Earth. For humans to be responsible stewards of this Earth, policies and ecological management must be based on understanding of the ecological processes that influence global change and the rates of ecosystem change in the future. Since biological organisms (plants, animals, microbes) carry out these ecological processes, changes in biological diversity also affect these processes. Of particular interest is providing national and international policymakers with quantitative information on how ecosystems both cause and respond to global change.

Research Needs and FY 1992 Program: Most of the USGCRP activities in this area support the Ecological Systems and Population Dynamics Integrating Theme and are described in that section. In addition to the research requirements associated with that Integrating Theme, the CEES agencies have identified the area of species diversity and change as an important area for future growth. The FY 1992 Budget includes specific enhancements to studies of biodiversity and biological conservation (SI and DOI); and USDA and NSF studies of changes in plants, microbes and pathogens in response to global change.

Human Interactions

Policy Relevance: Appreciation for the role of the biological, atmospheric, hydrologic, oceanic, solar, and terrestrial processes in changing the physical world is necessary, but not

sufficient. The relationships between these processes and the human activities that stimulate and mediate global changes must also be understood. Without an understanding of human interactions in global environmental change that is based both on empirical observations of human behavior and on a better understanding of the consequences of human actions, the models of physical and biological processes of change will be incomplete. Such links to human behavior are required for fully effective national and international policies to deal with global change.

Research Needs and FY 1992 Program: Human activities alter ongoing physical and biological processes through the long-term cumulative effects of individual actions, whose scope is influenced by social and economic institutions and systems throughout the world. Of particular interest are those human factors which influence such issues as: greenhouse warming; deforestation; soil erosion; and the loss of biodiversity. General relationships among different human and natural systems have been long identified, but the specific processes by which individuals and institutions interact with the environment over time have not been characterized. Especially critical is identification of the ways that human, physical, and biological systems interact, often through a complex feedback mechanisms.

In addition to the Human Interactions activities which support the Ecological Systems and Population Dynamics Integrating Theme, the FY 1992 Budget includes programmatic enhancements in the areas of: investigations of direct human action and indirect social, structural, and institutional influences on global change (NSF, EPA, DOE, DOI, USDA and the SI); the human health impacts of ozone depletion (EPA); and education, both scientific and technical training and public education. In addition, the FY 1992 Budget includes a major enhancement in the area of Economics Research Related to Global Change which is described separately under Special Issues.

Solid Earth Processes

Policy Relevance: Besides providing the key to deciphering environments preserved in the geological record, scientific observations of solid earth processes are essential to understanding the geologic processes that are most likely to affect the life-supporting elements of the global environment. In particular, these are the processes that are active at the interfaces between the surface of the Earth's lithosphere (subaerial and submarine) and the atmosphere, hydrosphere, cryosphere (collectively known as the geosphere), and the biosphere. Some solid earth processes have a global impact, although the phenomena occur locally or regionally, such as large explosive volcanic eruptions, the gas and particulate ejecta from which can cause significant climatic cooling for short periods of time. Other globally-distributed solid earth processes have a more restricted local or regional impact, but can have severe economic and destructive effects on regions of high population density. Examples include land subsidence in coastal areas, effusive volcanic eruptions, major dust storms, tsunamis, rapidly-changing sedimentation environments or the movement of tectonic plates that may result in earthquakes. Prudent mitigation policies require a substantially better understanding of these high impact phenomena.

Research Needs and FY 1992 Program: The CEES has identified a number of high-priority areas for solid earth processes investigations over the next several years, including: (i) the geological and ecological response of coastal regions to sea level rise, including coastal erosion, inundation, wetland loss, and the differentiation between climate change and tectonic processes as sources of sea level rise; (ii) the effects of volcanic emissions on regional and global climate; (iii) the nature and rate of the response of climatically-sensitive regions to climate change and human activities; and (iv) the cause and consequences of crustal deformation processes (e.g., uplift and earthquakes).

The FY 1992 Budget includes specific emphasis on CEES efforts to: understand volcanic

processes within the global ocean ridge system (NSF); field studies in active tectonics and volcanism (NSF, SI, DOI); investigations of the impact of sea level rise on coastal regions (DOI and SI); and the development and deployment of seismic and Global Positioning System (GPS) instrumentation (NSF and DOI).

Solar Influences

Policy Relevance: The sun is the principal natural forcing agent of the terrestrial environment. Understanding the immediate and more subtle roles of this forcing agent in governing global change is essential for an unambiguous separation between natural and anthropogenic changes. Currently, two of the three biggest concerns in the area of global environmental change--climate warming and stratospheric ozone depletion--are dependent on the radiative environment driven by the sun.

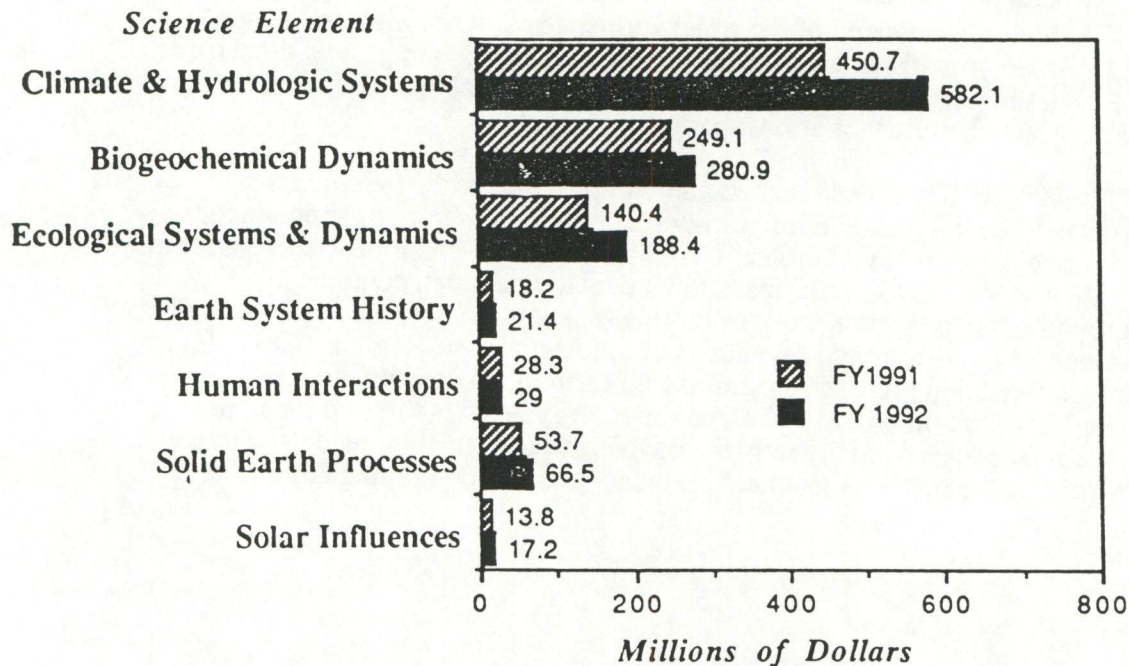
Research Needs and FY 1992 Program: The sun is the source of virtually all energy in the terrestrial environment; is a major driver of climate and atmospheric photochemistry, e.g. ozone; is the source of energy for all photosynthesis; and is the modulator of all radionuclides in paleo-studies, e.g. ^{14}C . One high priority need of the Solar Influences Science Element is the measurement of the relatively small fluctuations in solar output and their impact on the terrestrial system. This necessitates measurements from space, in particular total irradiance for climate and spectral irradiance for photochemistry of atmospheric constituents.

In early FY 1992 UARS will be launched and will provide for the first time a comprehensive array of solar inputs, including ultraviolet radiation (UV), and simultaneous atmospheric responses, e.g. ozone fluctuations. UARS will provide important data as a forerunner to the continuous monitoring of EOS. EOS instrument development will continue in FY 1992. Complementary ground-based programs will use remote sensing to observe the state of the upper atmosphere. The Coupled Energetics and Dynamics of the Atmosphere Regions (CEDAR) and Geospace Environment Modelling (GEM) programs will continue to develop the remote sensing technologies of radar, lidar, etc. in order to observe the solar induced inputs and the upper atmosphere responses. One objective is greatly improved global circulation models with a view to understanding the role that the upper atmosphere boundary plays in controlling atmospheric dynamics.

Budget by Science Element

Table 2 and Figure 3 show the FY 1991 enacted and FY 1992 proposed budgets for the USGCRP by science element. While the Program maintains an appropriate level of effort in all seven science elements consistent with the policy needs, science priorities identified by the IPCC science and impacts assessments, and the current state of both national (NAS) and international (WCRP and IGBP) scientific program development, the proposed FY 1992 activities focus primarily on the three highest priority science elements.

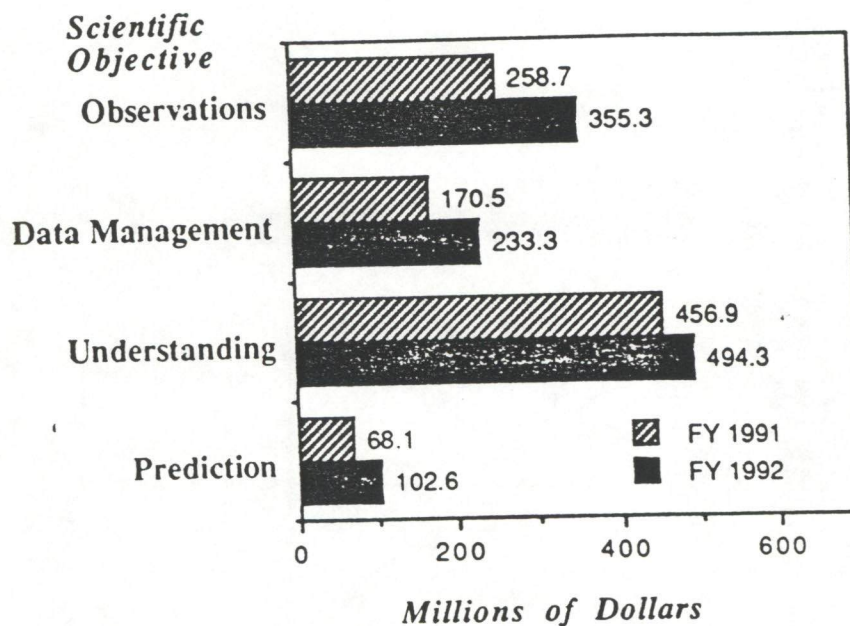
Figure 3
U.S. Global Change Research Program Budget
by Science Element



Budget by Scientific Objective

Table 3 and Figure 4 show the FY 1991 enacted and FY 1992 proposed budgets for the USGCRP by scientific objective: observations, data management, understanding and prediction. The proposed FY 1992 USGCRP Budget reflects a balance between each of the scientific objectives; a continued commitment to establish an integrated, comprehensive (space- and ground-based) atmosphere, ocean, and terrestrial observing system, which will acquire the long-term databases necessary for the development and testing of predictive models and for global change monitoring; and a strong commitment to an augmentation in climate modeling and prediction.

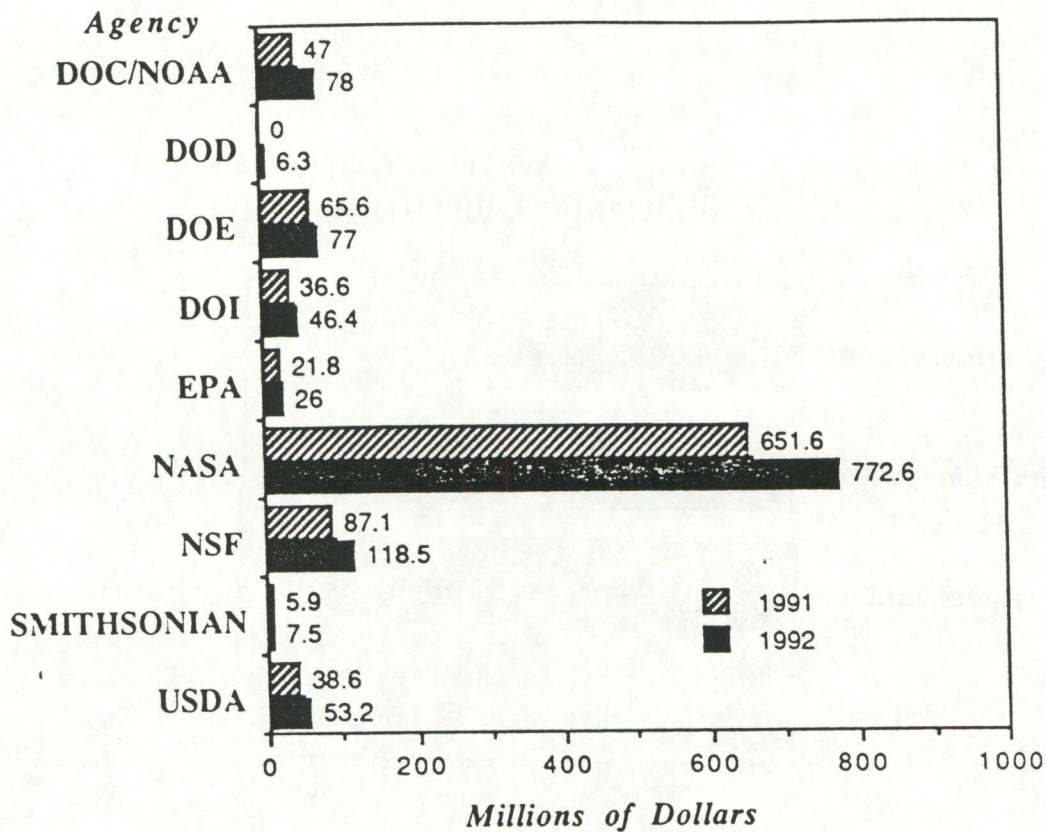
Figure 4
U.S. Global Change Research Program Budget
by Scientific Objective



Budget by Agency

Table 2 and Figure 5 shows the FY 1991 enacted and FY 1992 proposed budgets for the USGCRP by Agency. The individual agency efforts build upon their respective scientific and technical strengths.

Figure 5
U.S. Global Change Research Program Budget
by Agency



National Oceanic and Atmospheric Administration. In FY 1992, NOAA has proposed an \$78.0 million Climate and Global Change Program in support of the USGCRP. This represents a \$31.0 million or 66 percent increase over FY 1991. The FY 1992 NOAA contribution involves enhancements to ongoing efforts in: operational in situ and satellite observation programs with an emphasis on oceanic and atmospheric dynamics (including sea level), circulation, and chemistry; the development of new measurement techniques; focused research on ocean-atmosphere interactions, the global hydrological cycle, the role of oceanic circulation and biogeochemical dynamics in climate change, atmospheric trace gas/climate interactions, and the response of marine ecosystems and living resources to climate change and related stresses; and programs to improve climate modeling, prediction and information management capabilities. In addition, NOAA is expected to contribute to the evolving interagency program of global change economics research.

Department of Defense. In FY 1992, DOD has proposed a \$6.3 million budget for global change research. This represents the first year DOD has allocated funds as part of the focussed USGCRP. In general the funds support process oriented research and modeling in high latitudes, in boundary layer dynamics, and ecological dynamics that are relevant to DOD's missions.

Department of Energy. In FY 1992, DOE has proposed a \$77.0 million budget for global change research, a \$11.4 million or 17.4 percent increase above FY 1991 levels. The DOE maintains a research program directed at the impact of energy production and use on the global Earth system by focussing primarily on climate, atmospheric, ocean, and ecosystem responses. DOE will augment research on climate modeling; studies of carbon dioxide sources in the atmosphere, oceans, and land; and impacts on vegetation and ecosystems. New initiatives focus on critical data needs for global change research and the climatic variables that may serve as indicators of global change; on research efforts to quantitatively describe the radiative balance and the cloud-climate feedback in the atmosphere; and on funding to provide education and training to the next generation of scientists.

Department of the Interior. In FY 1992, DOI has proposed a \$46.4 million budget for global change research, a \$9.8 million or 21 percent increase above FY 1991 enacted levels. DOI efforts include studies of: paleoclimates; interaction and sensitivity of hydrologic, ecological, and landscape systems with climate and other natural forces; arid, polar, and coastal regions and systems; volcano-atmosphere interactions; methane hydrates; changing land surface characteristics; ocean heat fluxes; social, environmental, and economic consequences of global change including human activities, water resources, coastal wetland inundation, biological species and ecological system's characteristics and dynamics, and land management; and carbon cycle variation studies; as well as archiving and distributing space- and land-based Earth science data.

Environmental Protection Agency. In FY 1992, EPA has proposed \$26.0 million for global change research, an increase of \$4.2 million or 19.3 percent over the FY 1991 level. EPA's research efforts are focused on evaluating the processes and quantifying the relative contributions of anthropogenic and biological sources of trace gases, quantifying and modeling the consequences of climate change on ecosystems and their subsequent feedback to the atmosphere, and the interaction of trace gases in the atmosphere. Special emphasis will be given to climate sensitive regions, e.g. tundra and forests. EPA's research will help provide the process-level understanding and modeling capabilities to predict global change effects and feedbacks at the regional scale.

National Aeronautics and Space Administration. In FY 1992, NASA has proposed \$772.6 million for global change research, an increase of \$121.0 million or 18.6 percent above the FY 1991 level. NASA research efforts are primarily focused on space-based studies of the Earth as an integrated system. These activities include ongoing research and satellite programs (e.g., the Upper Atmosphere Research Satellite, Ocean Topography Experiment, etc.) that are important precursors to the FY 1991 initiatives: Earth Probes (a series of satellite measurements prior to EOS to monitor atmospheric ozone, ocean color, precipitation in the tropics, and ocean surface winds) and the Earth Observing System (EOS). EOS will provide an integrated, comprehensive monitoring and data management program of simultaneous measurements of key global change variables.

National Science Foundation. In FY 1992, NSF has proposed \$118.5 million for global change research, an increase of \$31.4 million or 36.1 percent above the FY 1991 level. NSF proposes to augment and initiate programs coordinated internationally to observe, understand, and model atmospheric, oceanic, terrestrial, polar, and social processes and their coupled interactions. Studies include ocean circulation, glacial dynamics, ocean-atmosphere interactions, cloud-radiation, global atmospheric chemistry, biogeochemical processes, land-sea interactions, past climate change, crustal and related processes impacting global change, ecosystems, solar

processes, human dimensions of global change, data bases, and climate system modeling and prediction.

Smithsonian Institution. In FY 1992, the SI has proposed a \$7.5 million budget for global change research, a \$1.6 million or 27.1 percent increase above FY 1991 levels. The Smithsonian's research concentrates on long-term documentation of ecosystem response to environmental change. In FY 1992, the SI efforts involve enhancements to ongoing research efforts in tropical forest ecosystem dynamics, characterization and quantification of biological diversity, terrestrial and marine ecosystem response to global climate, atmosphere-ecosystem exchange, past climate change and ecosystem response, human dimensions of global change and quantitative documentation of global volcanism and other natural components of global change.

United States Department of Agriculture. In FY 1992, USDA has proposed \$53.2 million for global change research, an increase of \$14.6 million or 37.8 percent above the FY 1991 level. USDA research efforts are focussed on ground-based research programs studying agricultural, forest and range ecosystems as influenced by factors such as water balance, atmospheric deposition, plant responses to changes in atmospheric constituents, UV-B radiation and other global change variables. Some representative studies that will focus on agricultural effects on environmental variables will include; effects of terrestrial ecosystems on water and energy fluxes to the atmosphere, mechanisms of methane generation and nitrous oxide release, soil properties including moisture, erosion, organic matter dynamics, nutrient fluxes, and microbes; relationship of global change to forest and range fires, insects, and plant pathogens; and, agricultural management systems.

Budget by Federal Budget Function

Scientific, environmental, energy, security, and agricultural resources are vital to the health of our nation. Table 5 shows the FY 1991 enacted and FY 1992 proposed budgets for the USGCRP by Federal budget function. In FY 1992, significant increases above FY 1991 levels are proposed for most budget functions. The USGCRP must be viewed as a single integrated research effort where its success is dependent upon cooperation and contributions from each of the individual agency programs as well as with other nations and international programs.

Table 5
1991 - 1992 U.S. Global Change Research Program Budget
by Budget Function
(Dollars in Millions)

Budget Function	Budget Function Number	1991	1992
TOTAL		954.2	1185.5
National Defense (DOD)	050	0	6.3
General Science, Space and Technology	250	738.7	891.1
NASA		651.6	772.6
NSF		87.1	118.5
Energy (DOE)	270	65.6	77.0
Natural Resources and Environment	300	105.4	150.4
DOI		36.6	46.4
EPA		21.8	26.0
DOC / NOAA		47.0	78.0
Agriculture (USDA)	350	38.6	53.2
Smithsonian	503	5.9	7.5

SPECIAL ISSUES

Data and Information Services

The global-scale and long-term nature of global change processes requires that continuous observations from many national and worldwide sources be used together synergistically to achieve scientific understanding and for the ultimate attainment of a predictive capability. This requires careful arrangements for managing the enormous volumes of data and information which will result from the observational programs. Because of the critical importance of data and information management in achieving the scientific objectives, this aspect of the U.S. Global Change Research program (USGCRP) has been emphasized strongly throughout the entire Program life cycle.

Success of the USGCRP will depend upon open access for the scientists to the full suite of data and information needed for their research. During the past year the CEES endorsed a set of data management principles, developed by the Interagency Working Group on Data Management for Global Change, which emphasize this need. They deal with early and continuing agency commitment to the production and preservation of high-quality, long-term data sets, data exchange standards, data access, and maintaining the lowest possible cost of data for research purposes. These principles are embodied within the USGCRP planning, and are being carried forward via the CEES as a basis for establishing national and international policy in this area.

The primary data management focus of the FY 1992 program is to take a set of initial steps to ensure that existing and emerging key data sets are preserved and made more readily accessible. Seven agency data management proposals are identified as being of critical importance to this end.

- o NASA's Earth Observing System Data and Information System (EOSDIS) will grow from 19% of the total EOS budget in 1991 to 25% in 1992. A set of early-EOS data and information activities will bring about improved use of existing data sets within the initial years, in advance of receipt of the larger capabilities required to handle the data flow from the full suite of EOS instruments. The EOS 1992 budget will make this early work possible while, at the same time, beginning the build-up toward the full EOS capability.
- o The DOE's Information/Coordination Program will improve access to, and use of, the Carbon Dioxide Information Analysis Center. This includes updating and maintaining the baseline carbon dioxide emissions data set, producing numeric data packages on trace gas emissions and concentrations, and updating publications to provide current information on climate and on emissions and concentrations of trace gases.
- o The DOI/USGS Land Data Program will provide improved access to space- and ground-based land data for global change research. In FY 1992, this will include continued operation of a prototype Global Land Information System with limited data sets; initiation of conversion of Landsat Thematic Mapper data to a stable storage medium; and developing and distributing global land data sets, beginning with satellite-derived vegetation index data and soils data for North America.
- o The Mission Operations and Data Analysis Program of NASA provides for the acquisition, processing, and archiving of long-term data sets produced by ongoing spaceborne missions. Missions covered by this proposal include Total Ozone Mapping Spectrometer (TOMS), Solar Backscatter Ultraviolet (SBUV), Stratospheric Aerosol Measurement

(SAM-II), Stratospheric Aerosol and Gas Experiment (SAGE-2), Earth Radiation Budget Experiment (ERBE), the Alaska Synthetic Aperture Radar (SAR) Facility, and Shuttle Imaging Radar (SIR-C).

- o NOAA, in its Information Management Systems Program, supports improvements to its data holdings in order to meet the needs of the USGCRP. In 1992, this will include first steps toward assembling and preparing widely-dispersed data holdings to form useful and cohesive long-term data bases, and toward addressing quality assurance, archival, and access problems within NOAA's National Climate, Geophysical, and Ocean Data Centers.
- o NOAA's Operational Measurements Program covers a number of NOAA activities which facilitate use of the operational satellite data and complement the other-agency programs. These include developing and providing information products from NOAA's operational satellites which will be used collectively with EOSDIS products.
- o The NSF Geosystems Data Bases Program will increase in FY 1992 to broaden existing projects to better meet the interdisciplinary needs of the USGCRP. These include exploratory research on value-added data and information products, e.g., model-assimilated information, the development of long-term data sets for studying and monitoring global change, and research on managing very large data sets. NSF will strengthen the data management infrastructure available to its global change scientific communities through, e.g., enhanced mass storage and retrieval capabilities for model data outputs.

In addition to these major data-intensive activities, most research programs include a substantial data management and analysis component directed toward the preparation and dissemination of data and information from those individual programs. These activities are also essential in making the broad range of new data and information easily usable for national and international global change research.

Space-Based Research

The proposed level of funding for space-based research programs in FY 1992 is \$461.6 million; an increase of \$22.8 million or 5.2 percent over the FY 1991 level. The proposed level of funding for EOS (observatories, instruments, data management, and scientific investigations) in FY 1992 is \$336.0 million, an increase of \$137.0 million over the FY 1991 level.

Maintaining an appropriate balance between ground- and space-based research programs is essential for a successful USGCRP. In-situ and theoretical studies of physical, chemical, biological and geological processes must be complemented by a comprehensive space-based program to provide the global observations of key environmental variables. The combination of ground- and space-based measurements is required given the temporal and spatial variability of the systems being studied, and the need to scale the processes occurring at the local level to the regional and global levels. The ground-based program is essential to interpret some of the global satellite observations (e.g., long-term trends), as well as obtain scientific information not attainable from space (e.g., trace gas fluxes). Both types of program need to be strongly supported.

U.S. scientific agencies are playing a key role in a number of interdisciplinary international scientific programs involving the land, oceans, and atmosphere, and interactions among them, that require a combination of ground- and space-based measurements for successful implementation. These programs include: World Ocean Circulation Experiment (WOCE); Tropical Ocean-Global atmosphere (TOGA); Global Ocean Flux Studies (GOFS); Global Ocean Ecosystems Dynamics

(GOED); GEWEX; IGAC; International Satellite Cloud Climatology Program (ISCCP); and International Satellite Land Surface Climatology Program (ISLSCP).

The proposed NASA space-based program is responsive to scientific and policy needs. The NASA space-based program includes: (i) EOS precursor satellite missions such as the Upper Atmosphere Research Satellite (UARS) to study the chemical, dynamical and radiative processes that control the abundance and distribution of stratospheric ozone, and TOPEX to study ocean circulation; (ii) a series of Earth Probes, including a Total Ozone Mapping Spectrometer (TOMS) to measure atmospheric ozone, a scatterometer (NSCAT) to measure ocean surface winds, a Tropical Rainfall Measurement Mission (TRMM) to measure precipitation in the tropics; (iii) Missions Operations and Data Analysis of satellite and shuttle experiments, including the current TOMS and ERBE data, and the planned Sea-Viewing, Wide Field Sensor (SeaWiFS) ocean color data, and (iv) EOS which will provide an integrated, comprehensive monitoring program of simultaneous measurements of key global change variables, coupled with a comprehensive data and information system.

Since the National Academy of Sciences (NAS) review of the USGCRP and EOS, NASA has undertaken feasibility studies of different approaches to implement EOS B, and to fly Clouds and Earth's Radiant Energy Systems (CERES) and Stratospheric Aerosol and Gas Experiment (SAGE) earlier than EOS A (for Earth radiation budget studies). NASA and CEES believe that the currently planned EOS and Earth Probes programs are essential components of the scientific program required to provide the scientific information required for national and international policy formulation with respect to key environmental issues. It should be noted that the configuration of the currently proposed EOS is scoped primarily to focus on the climate change (global warming) issue. To study climate change requires the following instruments currently under consideration for EOS A (Active Cavity Radiometer Irradiance Monitor (ACRIM), High-Resolution Imaging Spectrometer (HIRIS); Intermediate Thermal Infrared Radiometer (ITIR); Multi-Angle Imaging Spectro-Radiometer (MISR); Multiband Imaging Microwave Radiometer (MIMR); Moderate-Resolution Imaging Spectrometer (MODIS Nadir/Tilt); Stick Scatterometer (STIKSCAT); Atmospheric Infrared Sounder/Advanced Microwave Sounding Unit (AIRS/AMSU); CERES; SAGE; Earth Observing Scanning Polarimeter (EOSP); Measurement of Pollution in the Troposphere/Tropospheric Radiometer for Atmospheric Chemistry (MOPPITT/TRACER), and High-Resolution Dynamics Limb Sounder (HIRDLS)), and the following instruments currently under consideration for EOS B (Altimeter (ALT); Tropospheric Emission Spectrometer (TES); GPS Geosciences Instrument (GGI), and Geosciences Laser Ranging System (GLRS)). The only instruments currently being considered for EOS B that cannot be justified for studying climate change are those instruments devoted to stratospheric ozone (however, it should be noted that changes in the abundance of stratospheric ozone, especially near the tropopause, are predicted to affect tropospheric climate). This means that all of the currently planned EOS A instruments, and a significant portion of the EOS B instruments are needed for understanding climate change. The following list tracks potential EOS instruments to the areas of scientific uncertainty identified by Intergovernmental Panel on Climate Change (IPCC):

1. *sources and sinks of greenhouse gases:* AIRS/AMSU; HIRDLS; HIRIS; ITIR; MIMR; MODIS-N/T; MOPPITT/TRACER; SAGE; STIKSCAT; and TES;
2. *clouds and radiative balance:* ACRIM; AIRS/AMSU; CERES; EOSP; MIMR; MISR; and MODIS-N.
3. *oceans:* ALT; CERES; MIMR; MISR; MODIS-N/T; and STIKSCAT.
4. *land-surface hydrology:* HIRIS; ITIR; MIMR; MISR; and MODIS-N.
5. *polar ice sheets:* ALT; GGI; and GLRS; and

6. *ecological dynamics:* AIRS/AMSU; HIRIS; ITIR; MISR; and MODIS-N/T.

Economics Research Related to Global Change

Economics and economics research play an integral role in our ability to understand global change processes and evaluate critical policy issues. Importantly:

- o Economic activities play a central role in determining the level of energy and land use and industrial activity that contribute to global change.
- o Economic research and methods provide an important tool for evaluating the effects on society of global changes.
- o Economic considerations are important to evaluation of the costs and human consequences of actions that might possibly be taken to alter the timing or magnitude of global change, and thus to the choice of and among policy response options.
- o Economics, and the decision sciences more generally, can maximize the yield of knowledge relevant to decisionmaking by identifying which research results lie on the critical path for decisionmaking. Coordination of research efforts across the physical, biological, and social sciences to address these issues can improve the overall research program.

A full understanding of potential consequences of global environmental change, its causes, consequences, and possible responses, necessitates a thorough exploration of a broad range of economic factors. Increased recognition of the role that economics play in global change prediction and assessment is reflected in a substantial increase in the scope and funding of the economics research effort in FY 1992. As a consequence of a thorough analysis by an ad hoc Task Force of the CEES of economics research needs, the President's FY 1992 budget proposes \$17.5 million for global change economics research among seven agencies. This budget reflects an increase of \$9.3 million over FY 1991 enacted funding levels. This government-wide expanded research effort will address the five topical areas outlined below, about half of which is budgeted within the current USGCRP economics research program. The other part addresses additional and critical long-term research needs identified by the interagency committee, but which are more related to impacts, adaptation, and mitigation research. Short-term policy analyses, while very important, are not included. Further, this figure does not include increases in DOI's water resources research grants and NSF funding for international institutes, which will be used in part to support economics research. This research program is designed to substantially improve the depth of insight, enhance the credibility, and reduce the uncertainty of future policy analysis efforts.

The key strategic goal of the economics research effort is to build the economics knowledge base to enable sound policy analysis of global change issues. The economics research program will maintain an independent perspective and critically address the shortcomings of earlier work while building on its strengths. This strategic goal reflects an assessment that existing policy analyses have been hampered by a lack of fundamental economic research on resource-economy-environment interactions. The critical priorities of the economics research effort are to:

- o Document economic system and sector trends that determine economic inputs and sensitivities to global change throughout the world;
- o Focus studies on economic issues surrounding inputs, consequences, and responses to global change; and

- o Develop interdisciplinary linkages to address issues that crosscut the physical, biological, and economic sciences.

The CEES ad hoc Task Force identified five research foci for the economics research effort.

Economic Forces Affecting or Affected by Global Environmental Change

There is a critical need for improved understanding of economic forces driving technological change and productivity growth and of the underlying adaptive capability of economic sectors faced with climate changes. Patterns of growth may fundamentally affect global environmental change, and may be affected by both such change and policies instituted to respond to such change. Growth in economic output, productivity, population, and other variables needs to be considered, as well as their dependence on supplies of labor, capital, natural resources, human capital, and the state of technology and practices. Our understanding of growth determinants is generally quite detailed for industrialized countries, but requires substantial improvement for developing countries.

An ability to represent this improved understanding in economic models is also required. Modeling of economic activity affecting or affected by global environmental change and its relationship to the world economy at large is necessary to evaluate international market and trade effects and to develop consistent scenarios and predictions of trace gas emissions and global change effects. Such economic modeling exercises serve a parallel function and a critical predicate to GCM and carbon cycle modeling exercises in the physical and biological sciences, where improvement in methods and approaches is being vigorously pursued. Modeling exercises highlight the need to consider the full set of economic forces, responses, and adjustments including the dynamics of economic growth and international markets for energy, capital, food, currency, labor, timber, and other goods.

FY 1992 research budget in this area includes support for the development and refinement of aggregate global change models (DOE, EPA and USDA and NSF). In some cases, refinement will allow for more comprehensive consideration of human inputs to global change problems, while in others it will improve existing representations of human activities already included. DOE is focusing particular attention on developing countries, including China, that are expected to make a sharply rising contribution to global change, including climate change, in the future. EPA and USDA are pursuing economic studies of the international trade and competitiveness implications of response strategies and researching the augmentation of national income accounting systems to incorporate environmental considerations.

Impacts/Adaptation

Global environmental changes could have profound impacts on the very resources and systems (e.g., water, agriculture, forests, soil, and intensively managed and natural ecosystems) which determine the health, abundance, distribution, and well-being of human beings and other species. It is necessary to develop estimates of the social, economic, and environmental impacts of global changes over the long time frames in which such changes may occur and the capacity to relate or "index" these impacts to policy variables such as increments of emissions. Factors that need to be incorporated into impacts analyses include consideration of (a) adaptive measures that may be taken even in the absence of explicit (further) government intervention; (b) technical and management innovation that may reasonably be expected to occur over these time frames that might affect the vulnerability of sectors/systems; and (c) how current policies enhance or restrict the adaptive response of individuals and private firms.

FY 1992 research budget in this area includes support for research into issues surrounding impacts and responses to possible sea-level rise (EPA, DOI, DOD); empirical studies of impacts and their valuation and responses in the agricultural, range and forestry sectors (USDA); water resource economics issues and methodology development (DOI); and the valuation of non-market ecosystem change (EPA, USDA). Further, NSF will support work in several of these areas.

The Value of Information and Decisionmaking Under Uncertainty

Identifying key variables, understanding the value of information, and framing approaches to decisionmaking under uncertainty will be of great relevance to a number of global environmental change issues. One generic policy question is whether preventive action should be taken whenever there is any perceived risk, regardless of the value of first acquiring additional information. Another is the determination of the appropriate mix between policy intervention and additional research.

Irreversibility of species loss and other potential consequences of global change and the need to consider a time frame of 50 to 100 years or more pose special problems for economics and decision science research. Researchers must re-examine discounting and the general topic of valuing future outcomes and costs, drawing on approaches from both the social and physical sciences.

These issues, which involve interdisciplinary considerations, will be pursued in a major FY 1992 initiative at NOAA. NSF will sponsor research that addresses the ways that individuals, governments, businesses, and other institutions assess the present and future values of environmental characteristics. EPA, DOI, USDA and DOE are also pursuing research in this area.

Economic Forces Shaping Technology and Practice Linked to Global Environmental Change

Technology and practice are key factors in evaluating baseline conditions, impacts, and policy proposals related to global environmental changes. At the micro level, technologies and practices determine the rate at which inputs are transformed into outputs, including residual outputs (such as greenhouse gases) which may affect the global environment. Technologies and practices in all nations and across a wide range of sectors (including industry, energy, plant and animal agriculture, forestry, transportation, water, residential, commercial, and waste disposal) are relevant to global change issues.

Basic and applied research in the economics of technological progress is needed to develop an improved understanding of the spread of technologies and practices relevant to mitigation of or adaptation to global environmental change within and across countries, and how these diffusion rates and the rate of technical change itself are affected by policy, structural, institutional, legal, and financial factors, as well as by the anticipation of global environmental change itself. This work, together with efforts to reconcile the economic and engineering approaches to forecasting the application of technology, can help to clarify the relationship between technically possible and actually achievable outcomes.

FY 1992 research budget for this area includes support for energy technology assessments (DOE and EPA); study of technology transfer and diffusion processes (EPA, DOE, and NSF); agricultural and forestry technology issues relevant to impacts/adaptation/ and mitigation of global change (USDA). NSF is likely to support some additional research in this area.

Policy and Policy Instrument Evaluation

Economics research can make several important contributions to establishing a foundation for policy analysis. First, economics research can address issues in strategy, gaming, negotiation, compliance and enforcement that are relevant to the global change policy process. Second, research can examine the strengths and weaknesses of the types of generic policy instruments that are potentially applicable in the global change context. Finally, research can contribute to the development and refinement of tools, such as internationally linked macroeconomic models, that will play an important role in policy analysis. The FY 1992 research budget is designed to support research efforts at NSF, DOE, DOC, and DOD.

Education, Training and Human Resources

As part of the FY 1992 USGCRP, the CEES agencies have initiated several independent but coordinated efforts that will form the basis for and promote the development of an integrated global change education program in the future. Planning for a formal CEES Education initiative will continue during 1991 with limited funding potentially available for pilot projects in late FY 1991 and FY 1992. In addition, the education efforts of individual CEES agencies will continue to develop a qualified cadre of environmentally-oriented scientists to support the research needs of the USGCRP and its component agency programs. Graduate student development and postdoctoral opportunities will be available through NASA, NOAA, NSF, DOI, and DOE both in universities and at Federal research facilities. Emphasis in FY 1992 will be placed on interdisciplinary studies in climate and hydrological systems, biogeochemical cycling and climate modeling and analysis. Educator Training programs will continue in DOE and DOI with a focus on training elementary and high school science teachers and also provide advanced training for undergraduate teaching faculty. In the future, CEES agencies are expected to further enhance their global change education development programs in the areas of research experiences, educator training, and environmental education and outreach activities at all levels.

International Dimensions

The international global research aspects of the USGCRP are actively coordinated with those of other countries through a broad range of international arrangements. U.S. scientists work directly and very closely with their foreign counterparts in the planning of specific global change research programs such as the TOGA, WOCE; Core Projects of the International Geosphere-Biosphere Programme (IGBP) such as the Joint Global Ocean Flux Studies (JGOFS) and the International Global Atmospheric Chemistry (IGAC) Program; UNESCO's Man and the Biosphere (MAB) Program to use MAB Biosphere Reserves as global change research sites; and emerging national and international programs in the human dimensions of global environmental change, particularly global change economics research.

This planning has been led, in many instances, by joint activities of the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO), especially the Joint Scientific Committee (JSC) for the World Climate Research Program (WCRP). In addition, ICSU recently established a Scientific Committee for the International Geosphere-Biosphere Programme (IGBP). As these programs move from planning towards implementation, leadership for oversight and coordination shifts somewhat to intergovernmental organizations which, in concert with ICSU, are uniquely able to assist in broadening participation in and governmental support for global change research, particularly in developing countries. These organizations include the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), and the United Nations Environment Programme (UNEP). The U.S. shares in funding these program coordination activities through related U.S. national programs, augmented in some cases by direct funding of specific coordinating activities (e.g., the Scientific Committee for Oceanic Research (SCOR) of ICSU).

The U.S. agencies which fund global change research are also developing direct links with funding agencies in other countries, most notably on a multilateral basis through the newly-established informal International Group of Funding Agencies for Global Change Research (IGFA). Through this Group, the funding agencies discuss issues of common interest, including the identification of research gaps; the availability of facilities support such as ships and aircraft; and the joint development of mutually-supportive national contributions to international global change research projects.

The FY 1992 Program includes a new international initiative to create Regional Global Change Research Institutes (RGCRIs) particularly to address the regional implications of global change in economically-developing countries. The President invited other countries to join the U.S. in further developing this concept at the April 1990 White House Conference on Science and Economics Research Related to Global Change. The President's December 1990 trip to Latin America led to a specific FY 1992 initiative for creation of a Western Hemisphere RGCRi during FY 1992. The development of RGCRIs will follow the philosophy of the proposed Regional Research Centers of the IGBP. Detailed discussions with interested countries will continue throughout 1991 under the leadership of the White House Office of Science and Technology Policy and the CEES.

The funding by which the CEES agencies support such international coordination activities is provided through the specific national programs involved and, thus, are commensurate with the needs of each U.S. national program. Requests for such funding are reviewed by each agency in accordance with its normal review process. It is estimated that the U.S. provides slightly less than one-half of the total costs of these international coordination activities and that this percentage is decreasing steadily as more countries become directly involved in global change research.

Evolving Priorities

The overall constraints on Federal spending associated with the 1991 deficit reduction agreement led the CEES to pursue over the next five years a more focused USGCRP than originally proposed. While giving priority in the near-term to determining whether and how the physical climate system will change due to increasing concentrations of greenhouse gases, the USGCRP will continue to evolve in the future as new scientific developments and policy needs are identified. In the coming years, the CEES agencies, in concert with the national and international scientific communities, will continue to develop and review new scientific projects to support programs such as the IGBP and WCRP.

As projects are completed and priorities change, new higher-priority activities will be initiated. The composition of the USGCRP will evolve to reflect that progress. However, reallocations of effort will not suffice entirely to support continued USGCRP evolution, and the FY 1992 Program is offered with the caveat that in subsequent years, programmatic content and funding requirements should be re-evaluated to ensure a strong and effective U.S. commitment to global change research.

Program Management and Evaluation

The CEES Working Group on Global Change has initiated a comprehensive effort to develop and implement an overall coordination, program evaluation, and management strategy for the USGCRP. While recognizing agencies' responsibility to implement individual projects, this strategy fosters a process of collaboration focused on measuring progress, identifying gaps and assessing the effectiveness of agency activities. The management strategy takes a cooperative

approach to providing high priority global change predictions, assessments, and related information. Under such a management arrangement, meaningful performance measures for major elements of the Program will be developed and tracked, providing periodic evaluations of both individual projects and the USGCRP as an integrated effort. The anticipated management strategy will provide for continued evolution of the USGCRP in response to new scientific insights and future developments in national and international scientific planning efforts (e.g., the NAS Committee on Global Change, IGBP and the WCRP, etc.). Working Group plans also call for a management strategy which enhances the ability of the CEES to provide information on the status of the USGCRP as well as summaries of the state of scientific understanding on key components of the Earth System on a routine basis. Such a mechanism will improve the Committee's ability to serve the near-term needs of decision-makers while establishing the long-term scientific foundation for national and international global change policy formulation. The management strategy report will be published in late spring 1991, and will be fully implemented during FY 1992.

The allocation of resources by project reflected in this table are estimates only and are subject to change based on discussions of scientific and programmatic priorities among CEES agencies, their individual advisory mechanisms, and the broad national and international scientific communities.

APPENDIX

Fiscal Year (FY) 1991-1992 Global Change Research Program by Project
Dollars in Millions

Agency Bureau		Project	FY91	FY92
DOC	NOAA	Global Sea Level	3.8	4.8
DOC	NOAA	Upper Ocean Observations	3.1	5.2
DOC	NOAA	Operational Measurement	4.3	11.8
DOC	NOAA	Measurement Technique Development	0.3	1.2
DOC	NOAA	Information Management	4.6	7.0
DOC	NOAA	TOGA	6.0	6.8
DOC	NOAA	Clouds, Energy, Water	1.5	2.7
DOC	NOAA	Ocean Circulation/BGC	6.5	9.6
		(WOCE & Atlantic Climate Change)	(4.1)	(5.6)
		(Ocean Carbon & Marine Sulfur)	(2.4)	(4.1)
DOC	NOAA	Climate Modeling & Analysis	9.6	18.0
		(Near-Term Forecasting)	(0.6)	(2.2)
DOC	NOAA	Atmospheric Chemistry	5.0	6.3
DOC	NOAA	Marine Ecosystems	0.6	2.4
DOC	NOAA	Paleoclimate	1.7	2.2
DOC	NOAA	Economics Research	*TBD	TBD
DOC	NOAA	TOTAL	47.0	78.0
DOD	ONR	High Latitude Dynamics	0.0	2.7
DOD	ONR	Regional Resolving Models	0.0	1.0
DOD	ONR	Boundary Layer Dynamics	0.0	0.9
DOD	ONR	Ocean Ecological Dynamics	0.0	1.0
DOD	ONR	Ocean Measurements	0.0	0.2
DOD	CRREL	High Latitude Dynamics	0.0	0.3
DOD	CRREL	Regional Resolving Models	0.0	0.2
DOD		TOTAL	0.0	6.3
DOE	OHER	Core CO ₂ Research	26.4	23.1
DOE	OHER	CHAMMP	7.3	10.1
DOE	OHER	Information/Coordination	2.0	2.0
DOE	OHER	Resource Analysis	0.4	0.8
DOE	OHER	Oceans	4.0	6.0
DOE	OHER	Quantitative Link	5.0	4.8
DOE	OHER	ARM - Atmospheric Radiation Measurements	16.8	24.2
DOE	OHER	Data for Climate Modeling/Detection	1.2	2.0
DOE	OHER	Education	2.5	4.0
DOE	OHER	TOTAL	65.6	77.0
DOI	BIA	Unevenaged BIA Forests	0.0	0.1
DOI	BLM	Ecological Change in Environmentally Stressed Ecosystems of the Western & Northern U.S.	1.0	3.0
DOI	BOM	Methane Emissions from Coal Seams	0.0	0.1
DOI	BOR	Sensitivity of Hydrological Systems	1.0	1.1
DOI	BOR	Regional Studies	1.3	1.9
DOI	FWS	Coastal Wetland Change & Dynamics	1.0	1.3
DOI	FWS	Monitoring Fish & Wildlife Impacts	1.9	2.4
DOI	MMS	Coordinated Approach to Research of Social	0.0	0.4
DOI	NPS	Integrated Studies of NPS Ecosystems	1.8	3.3
DOI	NPS	Dynamics of Coastal Systems	0.1	0.3
DOI	USGS	Paleoclimates	7.2	8.4
DOI	USGS	Land Characterization	2.0	2.0

Draft: January 11, 1991

DOI	USGS	Interaction of Climate & Hydrologic Systems	6.1	5.2
DOI	USGS	Biogeochemical Exchanges	1.1	1.1
DOI	USGS	Volcano Emissions	0.4	0.4
DOI	USGS	Sensitivity of Water Resources	1.5	1.5
DOI	USGS	Cold Regions Research	0.9	1.4
DOI	USGS	Coastal Erosion & Wetlands Pro	3.0	3.0
DOI	USGS	Climates of Arid & Semi Arid Regions	0.9	0.9
DOI	USGS	Land Data	5.1	5.6
DOI	USGS	Extramural Research	0.0	1.4
DOI	USGS	Departmental Studies	0.25	1.6
TOTAL			36.55	46.4
DOI				
EPA	ORD	Emissions Research	5.0	5.5
EPA	ORD	Stratospheric Ozone	3.3	0.0
EPA	ORD	Emissions Research (Strat. Ozone)	0.0	2.7
EPA	ORD	Atmospheric Transport & Fate (Strat. Ozone)	0.0	0.7
EPA	ORD	Biospheric Transport & Fate (Strat. Ozone)	0.0	0.2
EPA	ORD	Human Health Effects (Strat. Ozone)	0.0	0.2
EPA	ORD	Ecological Effects	6.3	0.0
EPA	ORD	Terrestrial Biospheric Evaluation	0.0	4.2
EPA	ORD	Agroecosystem Effects (Strat. Ozone)	0.0	2.5
EPA	ORD	Marine Effects (Strat. Ozone)	0.0	0.7
EPA	ORD	Regional Climate	0.5	0.0
EPA	ORD	Biofeedbacks	5.7	0.0
EPA	ORD	Processes & Effects: Carbon Cycling	0.0	7.9
EPA	ORD	Marine Carbon Cycling	0.0	1.4
EPA	ORD	Tropospheric Chemistry	1.0	0.0
TOTAL			21.8	26.0
EPA				
NASA	OSSA	UARS-Upper Atmosphere Research Satellite	64.0	18.2
NASA	OSSA	TOPEX-Ocean Topography Experiment	76.0	51.9
NASA	OSSA	Payload & Instrument Development	49.7	48.6
NASA	OSSA	Mission Operations & Data Analysis	39.4	56.3
NASA	OSSA	Earth Observing System (EOS) Observatories	60.0	58.5
NASA	OSSA	EOS-Science	16.0	35.0
NASA	OSSA	EOS-Instruments	79.0	159.9
NASA	OSSA	EOS-Data Information Systems	36.0	82.6
NASA	OSSA	Earth Probes	54.7	68.2
NASA	OSSA	Construction of Facilities	9.0	17.0
Space-based Subtotal			483.8	596.2
NASA OSSA				
NASA	OSSA	Solid Earth Science	7.8	11.9
NASA	OSSA	Interdisciplinary Research & Analysis	12.4	2.5
NASA	OSSA	Suborbital Research Observations	20.2	20.3
NASA	OSSA	Model & Data Hydrology/Circ./Physical Climate	28.0	28.0
NASA	OSSA	Model & Data Solid Earth/Ecological Systems/		
		Biogeochemical Dynamics	16.3	17.0
NASA	OSSA	Hydrologic/Circulation/Physical Climate Processes	31.8	34.2
NASA	OSSA	Upper Atmosphere Research Program	28.3	30.9
NASA	OSSA	Laser Network	2.4	3.3
NASA	OSSA	Ecosystem Dynamics & Biogeochemical Processes	20.6	23.3
NASA	OSSA	RPA's	0.0	5.0
Ground-based Subtotal			167.8	176.4
NASA OSSA				
TOTAL			651.6	772.6
NASA				

Draft: January 11, 1991

NSF	GEO	ARCSS-Arctic System Science	7.7	9.4
NSF	GEO	CHP-Continental Hydrologic Processes	0.9	1.1
NSF	GEO	GEWEX-Global Energy & Water Cycle Experiment	0.1	0.4
NSF	GEO	ICMPA - Integrated Climate Modeling Analysis & Prediction	0.0	3.5
NSF	GEO	Role of Clouds	0.0	0.4
NSF	GEO	TOGA-Tropical Oceans-Global Atmosphere	10.6	14.7
NSF	GEO	WOCE-World Ocean Circulation Experiment	12.3	16.5
NSF	GEO	GTCP-Global Tropospheric Chemistry Program	11.0	13.5
NSF	GEO	JGOFS- Joint Global Ocean Flux Study	10.7	14.7
NSF	GEO	Ozone Depletion/UV Effects	5.6	5.6
NSF	GEO	Antarctic Ecosystems	1.5	2.5
NSF	BBS	EROC - Ecological Rates of Change	2.6	3.4
NSF	GEO	GLOBEC-Global Ocean Ecosystems Dynamics	1.4	3.5
NSF	GEO/BBS	LMER-Land-Margin Ecosystems Research	2.1	2.8
NSF	BBS	WEV-Water-Energy-Vegetation	0.0	0.1
NSF	GEO	Abrupt Climate Change	0.1	0.4
NSF	GEO	Geological Record of Global Change	1.5	1.8
NSF	GEO	Economics Research on Global Change	1.2	3.4
NSF	GEO	Human Dimensions of Global Environmental Change	2.4	3.4
NSF	GEO	Geodynamics	5.7	5.7
NSF	GEO	RIDGE-Ridge Interdisciplinary Global Experiment	3.9	3.9
NSF	GEO	CEDAR-Coupling, Energetics, & Dynamics of Atmos. Regions	4.1	4.7
NSF	GEO	GEM-Geospace Environment Modeling	0.3	0.8
NSF	GEO	Geosystems Databases	1.2	2.1
NSF	GEO/BBS	Global Change Education & Training	0.2	0.2
NSF	GEO	International Institutes	(0.0	2.0)*

NSF		TOTAL	87.1	118.5
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* Funding for International Institutes is distributed across other NSF activities.

SI	STRI	International Tropical Forest Dynamics	0.3	0.4
SI	STRI	Long-Term Environmental Monitoring	0.5	0.6
SI	STRI	Tropical Forest Canopy	0.4	0.4
SI	STRI	Biotic Responses to Atmospheric Change	0.1	0.1
SI	SERG	Chesapeake Bay Global Change	0.4	1.3
SI	NMNH	Amazonia Biological Diversity	0.8	0.8
SI	NMNH	Caribbean Coral Reef Ecosystems	0.4	0.4
SI	NZP	Global Change/Migratory Birds	0.3	0.3
SI	STRI	Tropical Agroforestry Program	0.2	0.2
SI	NMNH	Human Ecological History	0.1	0.4
SI	IC	SI/Man in the Biosphere	0.1	0.1
SI	NZP	International Conservation Biology	0.1	0.1
SI	SAO	Space Geodesy/Global Change	0.1	0.1
SI	NASM	Global Change in Earth's Drylands	0.3	0.3
SI	NMNH	Nile Delta and Global Change	0.1	0.1
SI	NMNH	Global Volcanism Program	0.4	0.4
SI	NMNH	Paleoecological Effects of Climate Change	1.0	1.2
SI	SAO	Atmospheric Chemistry	0.2	0.2
SI	SAO	Solar Studies/Global Change	0.1	0.1

SMITHSONIAN		TOTAL	5.9	7.5
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USDA	ARS	Biological Response to UV-B	0.7	0.7
USDA	ARS	Ecosystem Modeling	2.0	2.0
USDA	ARS	Biogeochemical Fluxes	2.0	2.0
USDA	ARS	Ozone Effects	0.4	0.4
USDA	ARS	Scale Effect of Hydro. Proc.	0.0	1.5
USDA	ARS	Pred. Impact on Sustain. Wtr	0.0	1.5
USDA	ARS	Time Change in Soil Carbon	0.0	1.0
USDA	CSRS	Stratospheric Ozone Depletion	9.4	9.4
USDA	CSRS	UV-B Monitoring Network	0.0	3.0
USDA	CSRS	Energy-Methane Sources, Biomass Fuels	0.0	2.0

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USDA	SCS	Pedosphere-Paleoecology	0.8	0.8
USDA	SCS	Pedosphere-Processes	0.7	0.7
USDA	FS	Energy, Water, Carbon & Nutrient Cycles	7.5	8.0
USDA	FS	Species Life History	6.7	7.0
USDA	FS	Water Yield, Erosion & Sedimentation	2.3	2.8
USDA	FS	Fire Severity	2.3	2.5
USDA	FS	Aquatic Ecosystems & Fisheries Habitat	1.4	1.3
USDA	FS	Wildlife/Domestic Species Interactions	0.6	0.9
USDA	FS	Microbes, Plant Pathogens & Insects	1.8	1.4
USDA	FS	Economics	0.0	1.5
USDA	ERS	Econ. Sys. & Global Change	0.0	0.5
USDA	ERS	Economics	0.0	2.3
TOTAL			38.6	53.2
USDA				

Agency Acronyms		
DOC	NOAA	National Oceanic and Atmospheric Administration
DOD	ONR	Office of Naval Research
	CRREL	Cold Regions Research and Engineering Laboratory
DOE	OHER	Office of Health & Environmental Research
DOI	BIA	Bureau of Indian Affairs
	BLM	Bureau of Land Management
	BOM	Bureau of Mines
	BOR	Bureau of Reclamation
	FWS	Fish & Wildlife Service
	MMS	Minerals Management Service
	NPS	National Park Service
	USGS	U.S. Geological Survey
EPA	ORD	Office of Research & Development
NASA	OSSA	Office of Space Science & Applications
NSF	BBS	Biological Behavioral & Social Sciences Directorate
	GEO	Geosciences Directorate
SI	STRI	Smithsonian Tropical Research institute
	SERC	Smithsonian Environmental Research Center
	NMNH	Natural Museum of Natural History
	NZP	National Zoological park
	IC	International Center
	SAO	Smithsonian Astrophysical Observatory
	NASM	National Air and Space Museum
USDA	ARS	Agriculture Research Service
	CSRS	Cooperative State Research Service
	ERS	Economic Research Service
	FS	Forest Service
	SCS	Soil Conservation Service

*Pending discussions of programmatic and scientific priorities with NOAA management, the external advisory panel for the Climate and Global Change Program and other CEES agencies, up to \$2.0M in FY 1992 resources could be applied to NOAA support of the interagency Global Change Economics Research Program (with possible offsetting reductions in other C&GC projects).