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

RUSH

DATE: _____

TO: Jeff Hornshead

ADDRESS:

TELEPHONE NUMBER: 7929

FAX NUMBER:

FROM: Ken Yale

TELEPHONE NUMBER:

FAX NUMBER: (202)395-3261

NUMBER OF PAGES, INCLUDING COVER SHEET _____

SPECIAL INSTRUCTIONS:

02/12/91

23:36

WESTFIELDS U S

002

12 February 1991
9:30 pm

I. GUIDELINES FOR THE NEGOTIATIONS:

1. All items in the negotiations should be dealt with in an integrated manner. *and on the basis of Resolution 45/12 of the General Assembly.*
2. The work of the groups must be interrelated and will be integrated by the plenary. To this end the two Working Groups will report regularly to Plenary.
3. Funding commitments, mechanisms and means for transfer of technology to developing countries, as well as matters of international scientific and technological co-operation, should be an integral element of all relevant deliberations [and any final agreement or commitment].
4. The final agreement on the Convention should cover all areas of common concern, including inter alia : (a) emissions; (b) sinks; (c) transfer of technology, (d) financial resources, and funding mechanisms ~~for developing countries~~; (e) international scientific and technological cooperation; and (f) measures to counter the effects of climate change, and its possible adverse impact, particularly on small island developing countries, low lying coastal, arid and semi-arid areas.

II. ORGANIZATION OF WORKING GROUPS

The Working Groups will prepare draft text for consideration by the Plenary.

Working Group I - Commitments

Preparation of text related to:

- Appropriate commitments, beyond those required by existing agreements, for limiting and reducing net emissions of CO₂ and other greenhouse gases. Appropriate commitments on the protection, enhancement and increase of sinks and reservoirs. Appropriate commitments in support of measures to counter the effect of climate change. *these*
- ~~Contributions to this commitment~~ should be equitably differentiated according to countries' responsibilities and the level of development.
- Commitments related to the recommendations of the SWCC ministerial declaration, paragraph 15:

02/12/91

23:37

WESTFIELDS U S

003

"We recognize that developing countries have as their main priority alleviating poverty and achieving social and economic development and that their net emission must grow from their, as yet, relatively low energy consumption to accommodate their development needs. Narrowing the gap between the developed and the developing world would provide a basis for a full partnership of all nations and would assist the developing countries in dealing with the climate change issue. To enable developing countries to meet incremental costs required to take the necessary measures to address climate change and sea level rise, consistent with their development needs, we recommend that adequate and additional financial resources should be mobilized and best available environmentally sound technologies transferred expeditiously on a fair and most favorable basis. Developing countries also should, within the limits feasible, take action in this regard."

- Commitments addressing the special situation of developing countries, taking into account their development needs, including, inter alia, the problems of small island developing countries, low-lying coastal areas and areas threatened by erosion, flooding, desertification, and high urban atmospheric pollution, as well as the problems of economies in transition.

Working Group II - Mechanisms

Preparation of text related to:

- Legal and institutional mechanisms including, inter alia, entry into force, withdrawal, compliance, and assessment and review.
- Legal and institutional mechanisms related to scientific cooperation, monitoring and information.
- Legal and institutional mechanisms related to adequate and additional financial resources and technological needs and cooperation, and technology transfer to developing countries corresponding to the commitments agreed to in Working Group I.

02/12/91

23:37

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004

III. PROCEDURAL POINTS

1. There will be no more than two meetings held at any one time within the INC.
2. There will be no inter-sessional meetings of the INC Working Groups or any sub-groups.
3. All drafting is to be done by each Working Group, within the framework of its mandate, subject to any subsequent need for harmonization.
4. If and when it is deemed necessary, the Working Groups, subject to the approval of the INC, may establish ad-hoc sub-groups to deal with specific issues, with due respect to the understanding of not having more than two meetings at the same time. These groups would be reviewed continually to allow reformulation and adjustment to reflect the progress of the negotiations.

EC PROPOSAL ON INC WORKING GROUPS

(drawing on ideas of the G-77 and the "common ground approach")

I. ORGANISATION OF WORKING GROUPS

The Working Groups will prepare draft texts for consideration by the Plenary.

Working Group I - Commitments

Preparation of text related to:

- * commitments on sources and sinks and related financial and technical needs and assistance, including technology transfer;
- * commitments addressing the special situation of developing countries, including the problems of low-lying areas and islands and areas threatened by erosion, desertification and high urban pollution, as well as the problems of economies in transition.

Priorities for discussion in Working Group I should be [objectives and measures concerning

- * ^{imitation} stabilisation and/or reduction of ^{net} environmentally harmful emissions of GHG's, particularly CO₂ in the atmosphere;
- * protection, enhancement and increase of sinks and reservoirs;
- * related financial assistance and technology development and transfer.

Working Group II - Mechanisms

Preparation of text related to:

- * legal and institutional mechanisms, including inter alia entry into force, withdrawal, compliance, and assessment and review;
- * mechanisms related to scientific cooperation, monitoring and information exchange;
- * elaboration of mechanisms related to financial and technical needs and assistance, including technology transfer, as developed by Working Group I.

II. PROCEDURAL POINTS

1. The two Working Groups will report regularly to Plenary, which will coordinate their work and carry it forward where appropriate. The work of the groups must be interrelated and will be integrated by the Plenary.
2. There will be no more than two meetings held at any one time within the INC.
3. There will be no intersessional meetings of the INC Working Groups or any sub-groups.

DOE like
to delete phrase

DOJ, DOT,
others
suggest
replacing
"particularly"
with "including"
or
"with due regard to
the importance of"

DOE, NASA, DOT
proposal
(consensus)

4. All drafting is to be done by each respective Working Group, subject to any subsequent need for harmonisation and legal finalisation.,
5. The Working Groups can establish ad-hoc sub-groups *in light of the discussion of* to deal with priority *priority* *issues* issues with due respect to the understanding of not having more than two meetings at the same time. These groups would be reviewed continually to allow reformulation and adjustment to reflect the progress of the negotiations.

Draft points to make
(merely suggestive)

Welcome:

Welcome national delegates, international organizations and NGOs. Delighted to host all of you in D.C.

This informal discussion is not for press coverage; it's off the record; this is a substantive interchange among interested persons. None of the views expressed by the panelists -- or the audience -- are necessarily national views.

US has provided booklets on "comprehensive approach." Additional copies are available at the door. This discussion picks up on the information in those booklets.

Introduce panelists.

Introduction:

Comprehensive approach is an approach to all aspects of human interactions with climate. It applies to scientific understanding of the climate system, to predicting potential climate change, to developing national strategies, and to designing any assistance or policy measures.

The US has taken a comprehensive approach to developing a national strategy. We are pursuing several actions that will keep net greenhouse emissions from growing through 2000.

Why a comprehensive approach is important: necessary to match the complex climate system. Experience shows that trying to address environmental issues in a piecemeal fashion is more costly, and less environmentally effective.

Science:

Climate system: many gases, sources, sinks. Each gas has different attributes (radiative forcing, lifetime, reactivity).

Need to account for net emissions of all gases in order to understand and predict potential climate change. Looking only at one gas would give incomplete picture.

Key areas to improve knowledge (e.g. CO₂ lifetime; atmospheric interactions of CH₄, CO, OH, etc.; CH₄ and N₂O emissions from diffuse sources).

Convention can help advance this work (refer to US "science annex" and its rationale).

- Draft points, p. 2 -

Economics:

Externalities; need for a means to guide private choices toward social goals. Guide should reflect environmental quality goals; here the variable of concern is potential global warming, not emissions of any specific gas.

Approach needs to match environmental system. Taking a narrow view undermines environmental effectiveness. Example from experience: air-water-land cross-media shifts. Example in climate: switching from coal to natural gas reduces CO2 but increases CH4; in some areas (e.g. Eastern Europe), the result could even be a net increase in potential warming.

The approach should allow maximum flexibility for diverse and innovative efforts. Narrow approaches limit flexibility and increase costs. Different nations have different greenhouse gas emissions portfolios, and need flexibility to design national strategies to meet their own circumstances.

Transition to Q & A:

Recognize other US Government representatives in attendance, such as Edith Brown-Weiss (Head of international law, EPA); Rick Bradley (special assistant to the Secretary of Energy for environmental issues); someone from State Dept.; etc.

Conclusion at 7 pm:

Could note Japanese reception, encourage all to attend.

Some Key Likely Questions

- Does the "Action Agenda" indicate that the US is now willing to agree to targets & timetables?

(Draft answer: No. Every nation has different circumstances and needs to fashion its own response; a uniform target covering all nations would be too rigid and premature in light of uncertainties. A better approach is "bottoms-up" -- each nation showing what it is accomplishing through a national strategy. That is what we have presented in our brochure.)

- The US Action Agenda shows no growth in US emissions through 2000, but using the same accounting basis, other nations could show substantial reductions (e.g. Germany).

(That's fine; each strategy is up to each nation. Also, we are showing real programs, not declarations or promises. The main point is to take a comprehensive approach. For example, have these nations (e.g. eastern Germany) accounted for the methane emissions that will result as they switch to natural gas distribution?)

- How can you countenance counting CFCs when they're already covered by the Montreal Protocol?

(CFCs' global warming potential is not covered in the Montreal Protocol. Nor does the Protocol effectively address CFC-substitutes such as HCFCs, which could contribute to significant warming potential. And the Protocol does not address the large stock/reservoir of CFCs (e.g. in old refrigerators and air conditioners). Including CFCs makes scientific sense, and it provides additional incentives to phase them out and to address the stock/reservoir. Excluding CFCs from the accounting would create perverse incentives not to reduce CFCs and HCFCs, especially among nations not yet party to the Montreal Protocol.)

(All elaborated in booklet, pp. 73-75.)

- Comprehensive approach means delay; it's too complex or unworkable.

(Better to do the needed groundwork than to plunge ahead with a piecemeal approach at high cost and limited effectiveness; comprehensive approach can be phased as long as the framework is appropriately broad to begin with; if we start piecemeal it'll become entrenched. Not unworkable, indeed offers flexibility to diverse nations.) (See "Comp. Approach" booklet, pp. 70-73.)



GLOBAL CLIMATE COALITION

JOINT STATEMENT
BY
INDUSTRY/BUSINESS NON-GOVERNMENTAL ORGANIZATIONS
AT
INTERGOVERNMENTAL NEGOTIATING COMMITTEE FOR A
FRAMEWORK CONVENTION ON CLIMATE CHANGE
WASHINGTON, D.C.
4-14, FEBRUARY, 1991

Thank you for this opportunity to address the Intergovernmental Negotiating Committee, Mr. Chairman. I am speaking on behalf of the Global Climate Coalition and other industry and business Non-Governmental Organizations which represent companies and associations with operations throughout the world. The Global Climate Coalition is a broad-based ad hoc association of more than seventy business trade associations and companies which have come together to deal with issues related to global climate change. We build and operate facilities that employ millions of people, and provide goods and services to maintain and improve the lives of everyone. We are producers and consumers of energy. We also live and work on this planet and are concerned for its well being.

We are here today as observers because our organizations appreciate the seriousness of the issues you must address. Indeed, many of us have participated in the scientific and public policy debate surrounding potential climate change for many years. We are aware of the great complexity and uncertainty that characterize today's limited scientific understanding of future climate change, and its impacts. With the Response Strategies Working Group of the IPCC we recognize the formidable difficulty this lack of knowledge creates for policy makers. As several speakers have noted, we also recognize the limited understanding available today on the feasibility, costs, and associated impacts of policies to limit climate change concerns. We favor policies that are beneficial for reasons other than climate change and justifiable in their own right.

We are here as observers, and we are prepared to contribute as appropriate to the deliberations of the Negotiating Committee, its Working Groups and National Delegations. We are confident that you understand that business and industry and, therefore the consumers of goods and services throughout the entire world will be expected to bear the cost and effort in developing and implementing any effective responses to climate change concerns. Business and industry will be especially involved through our continuing work in research, development, commercialization and transfer of efficient, environmentally sound technologies to address these issues over the coming decades.

One of the ways that business and industry will play a constructive role is the application and transfer of technology to deal with energy and environmental needs. Business and industry's participation in environmental technology transfer is of critical importance. In fact, technology transfer is principally a business and industry activity rather than a government to government activity. The worldwide movements away from centrally planned economies toward private markets further underscore this fact. International technology transfer discussions should recognize that such transfers must be on a prudent and economic basis for all parties to these transactions.

Mr. Chairman, we also extend an offer to participate as appropriate in the technical deliberations that will aid your negotiations. Our organizations have relevant expertise in our scientists, engineers, economists, analysts and planners. In this respect we welcome the comments of Professor Bolin, Chair of the IPCC, to involve NGOs and appropriate individual experts in the future activities of the IPCC, and we note his desire to extend IPCC efforts to analyze costs and benefits of potential responses to climate change. We believe that we have experts and knowledge to contribute to those assessments. As we noted already, we in business and industry will be expected to have the major role in implementing any necessary response policies, and we believe that our practical knowledge in these matters is relevant and necessary.

Finally, Mr. Chairman, we join in the remarks expressed by several delegations, that the response to concerns over potential climate change must be adaptive and flexible. Over the long term, we must be in a position to make best use of the growing scientific understanding of the climate system, developments in technology, and increased awareness of the economic implications of government policies.

Delivered By:
John Shlaes
of Edison Electric Institute
and the Global Climate Coalition
on behalf of International
Business and Industry Organizations

CHANGING BY DEGREES

STEPS TO REDUCE GREENHOUSE GASES

S U M M A R Y



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JOSEPH E. ROSS
Director
Congressional Research Service
The Library of Congress
Washington, D.C.

JOHN F.M. SIMS
Vice President, Marketing
Usibelli Coal Mine, Inc.
Fairbanks, Alaska

MARINA v.N. WHITMAN
Vice President & Group Executive
Public Affairs Staffs Group
General Motors Corporation
Detroit, Michigan

Director

JOHN H. GIBBONS

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Gene Carl Feldman, NASA, created the cover from a Mosaic satellite image "The Earth at Night" (© 1985) compiled by W.T. Sullivan, III, University of Washington from satellite photographs made by the Defense Meteorological Satellite Program of the U.S. Air Force, Feldman converted the original black and white photograph from a Mercator Projection of the Earth into two orthographic projections. The colors depict sources of CO₂ emissions: white, lights of cities; red, forest and agricultural fires; yellow, gas flares.

CHANGING BY DEGREES

STEPS TO REDUCE GREENHOUSE GASES

S U M M A R Y



CONGRESS OF THE UNITED STATES
OFFICE OF TECHNOLOGY ASSESSMENT

Contents

	<i>Page</i>
CLIMATE CHANGE AND GREENHOUSE GASES	3
U.S. SECTORAL ANALYSES AND PROJECTIONS OF CO ₂ EMISSIONS	7
Current Emissions	7
Future Emissions Scenarios	8
Costs	9
OPTIONS FOR REDUCING U.S. EMISSIONS	12
Technical Options	12
Policy Instruments	13
Sectoral Policy Options	17
U.S. INFLUENCE ON THE REST OF THE WORLD	31
Developing Countries	32
U.S.S.R. and Eastern Europe	33
U.S. Policy Options To Help Limit Greenhouse Gas Emissions Abroad	33
CONCLUDING REMARKS	41
REFERENCES	42

Boxes

<i>Box</i>	<i>Page</i>
1-A. The OTA Study in Context	4
1-B. The OTA CO ₂ Emissions Reduction Model	10
1-C. Agencies and Organizations That Can Influence Greenhouse Emissions Abroad ..	35

Figures

<i>Figure</i>	<i>Page</i>
1-1. Greenhouse Gas Emissions in 1985, by Region, and the Contribution of Each Greenhouse Gas to Global Warming in the 1980s	5
1-2. Summary of OTA's Analysis of Carbon Emissions With and Without "Moderate" and "Tough" Controls	6
1-3. U.S. Energy Consumption and Associated Carbon Emissions in 1989	7
1-4. 1987 U.S. CO ₂ Emissions by Sector	8
1-5. Carbon Emissions Under the Base Case, Moderate, and Tough Scenarios	9
1-6. Federal Government Funding for Energy Supply R&D, 1980 to 1990	16
1-7. Demand-Side Measures	17
1-8. Electric Utility Supply-Side Measures	25
1-9. Forestry Measures	28
1-10. Per Capita Energy Consumption	33
1-11. World Population Growth, 1750-2100	33

Tables

<i>Table</i>	<i>Page</i>
1-1. Measures To Lower U.S. Carbon Emissions	11
1-2. Policy Instruments To Reduce CO ₂	14

Foreword

The United States has a history as a Nation of working towards a common goal. It has demonstrated this in time of war, in landing a man on the moon, and in reducing energy use during the oil crises of the 1970s. However, in each case, the effort was sustained less than a decade; the desired goals were achieved or the crises passed.

The United States is the world's leading industrial society and largest single emitter of carbon dioxide. Climate change therefore presents a unique challenge to this Nation. It is a threat that will require major prudent political actions even before all the scientific certainties are resolved. The analysis, prevention, and remediation of global warming will require unprecedented international cooperation and action—an effort requiring actions sustained over decades, not just a few years.

Carbon dioxide and chlorofluorocarbon (CFC) emissions are responsible for 80 percent of the “global warming commitment” caused by human activities over the last decade. A landmark international agreement to totally phase out the use of CFCs by the year 2000 is already in effect. Many of the nations involved in that accord are now seeking ways to reduce the carbon dioxide emissions. This task is clearly more daunting since most industrialized nations currently depend so heavily on fossil fuels—the major source of carbon dioxide—for their economic well-being.

For this reason, this assessment focuses principally on ways to cut carbon dioxide emissions both in the United States and in other countries as well, although it does examine all greenhouse gases. The report responds to the concerns of six Committees of Congress who requested in 1988 that OTA undertake this study. The Senate requesting Committees are: Commerce, Science, and Transportation; Energy and Natural Resources; Environment and Public Works; and Governmental Affairs. The House requesters are: Committee on Science, Space, and Technology; and the Committee on Foreign Affairs.

This assessment shows that major reductions of carbon dioxide and other greenhouse gases will require significant new initiatives by the Federal Government, by the private sector, and by individual citizens. Many of these initiatives will pay for themselves; for others, the economic cost may be considerable. And many of these efforts must be sustained over decades.

Although many ancillary environmental benefits will accrue from the actions necessary to effect a major reduction of U.S. carbon dioxide emissions, such a decrease will not, in itself, significantly decrease the greenhouse effect. Other nations will have to take similar actions and, even then, those actions will only slow any warming trend. An Intergovernmental Panel on Climate Change and the U.S. Environmental Protection Agency estimated that at least a 50- to 80-percent worldwide reduction in carbon dioxide emissions is needed to keep the atmosphere at today's already altered level.

That level of reduction requires the world to wean itself from fossil fuels if it hopes to keep emissions from growing steeply under the combined pressure of economic and population growth. Steps taken now to use more efficient energy technologies would reduce emissions while buying time required for the transition to nonfossil fuels.

OTA appreciates the support this effort received from hundreds of contributors both from the United States and abroad. Workshop participants, reviewers, contractors, and informal advisers provided OTA invaluable support as it attempted to sift through the voluminous material on this subject. OTA, however, remains solely responsible for the contents of this report.



JOHN H. GIBBONS
Director

Changing By Degrees: Steps To Reduce Greenhouse Gases

OTA Project Staff

John Andelin, *Assistant Director, OTA*
Science, Information, and Natural Resources Division

Robert Niblock, *Oceans and Environment Program Manager*

Rosina M. Bierbaum, *Project Director*

Robert M. Friedman, *Senior Associate*

Howard Levenson, *Senior Associate*

Richard D. Rapoport, *Analyst*

Nick Sundt, *Analyst*

Research Assistants

Jennifer H. Cohen

Stanislav F. Kolar

Other Contributors

David Festa

Gretchen Kolsrud

Susan Kulakowski

Jana Milford

Mark Pastore

Linda Sawyer

Dan Schechter

Rhodri Walters

Eric Washburn

Frances Wood

Fred Wood

Andrew Wyckoff

Contractors

Susan Wintsch, *Editor*

Battelle, Pacific Northwest Laboratories

Enterprise Development International, Inc.

Murray Feshbach

International Resources Group, Ltd.

Don Kash

Vicki Norberg-Bohm

Pacific Institute (SIDES)

Edward A. Parson

Princeton University

University of Washington

Michael P. Walsh

Administrative Staff

Kathleen A. Beil

Sally W. Van Aller

Assessment Advisory Groups

Advisory Group on Buildings

Fred Abel	Erik Haites
Senior Economist	Principal
Office of Building Technologies	Barakat & Chamberlin
U.S. Department of Energy	
Edward Baily	Cheryl Harrington
Vice President	Commissioner
Government and Industry Relations	Maine Public Utilities Commission
Carrier Corp.	
Douglas C. Bauer	Michael Joroff
Senior Vice President	Director, Laboratory of Architecture
ERC Environmental & Energy Services Co.	and Planning
	Massachusetts Institute of Technology
G.Z. Brown	Henry Kelly
Professor of Architecture	Senior Associate
Department of Architecture	Office of Technology Assessment
University of Oregon	
William Chandler	David MacFadyen
Director, Advanced International Studies Unit	President
Battelle, Pacific Northwest Laboratories	NAHB National Research Center
Armond Cohen	Alan Miller
Senior Attorney	Director
Conservation Law Foundation	Center for Global Change
	University of Maryland
Drury Crawley	John P. Millhone
Senior Research Scientist	Deputy Assistant Secretary
Pacific Northwest Laboratories	Office of Building Technologies
	U.S. Department of Energy
Daniel Dreyfus	Ronald Morony
Strategic Analysis/Energy Forecasting	Director, Innovative Technology and Research
Gas Research Institute	U.S. Department of Housing and
	Urban Development
Ezra Ehrenkrantz	
President	Brad W. Oberg
The Ehrenkrantz Group	Program Manager
	New Systems Laboratory
Dave Engel	USG Corp.
Deputy Division Director	
Technology and Research Division	Bill Prindle
U.S. Department of Housing and	Senior Program Manager
Urban Development	Alliance to Save Energy
Charles Field	Art Rosenfeld
Staff Vice President	Director, Center for Building Science
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Howard Geller	John Scalzi
Associate Director	Program Director, Structures and Building Systems
American Council for an Energy-Efficient Economy	National Science Foundation
Jim Gross	John Slayter
Deputy Director	Director of Research and Engineering
Center for Building Technology	The Ryland Group
National Institute of Standards and Technology	

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory group members. The groups do not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

Peter Smeallia
Director, Geotechnical Board
National Research Council

Bill Staubitz
Manager Marketing Development
Sylvania Corp./GTE

Mary Tucker
Acting Manager, Energy Program
City of San Jose, CA

Steven Winter
President
Steven Winter Associates, Inc.

Richard Wright
Director
Center for Building Technology
National Institute of Standards and Technology

Advisory Group on Industry

John Barker
Vice President, Energy Affairs
ARMCO Inc.

Deborah Bleviss
Executive Director
International Institute for Energy Conservation

Kenneth Burgess
Vice President
Dow Chemical Co.

William Chandler
Director, Advanced International Studies Unit
Battelle, Pacific Northwest Laboratories

Thomas J. Gross
Director, Improved Energy Productivity
U.S. Department of Energy

Hillard G. Huntington
Senior Research Associate
Energy Modeling Forum
Stanford University

Martin Klepper, Esq.
Partner
Skadden Arps

Paul Leiby
Economist
Oak Ridge National Laboratory

Alastair McKechnie
Chief, Energy Efficiency and Strategy Unit
Industry and Energy Department
World Bank

Jeremy Metz
Director, Energy, Materials, and Technology
American Paper Institute

Steve Rayner
Coordinator, Policy, Energy and
Human Systems Analysis
Center for Global Environmental Studies
Oak Ridge National Laboratory

Joe Roop
Staff Scientist
International Energy Agency
Organization for Economic Cooperation
& Development

Marc Ross
Professor
Physics Department
University of Michigan

Irv Snyder
Director, Research and Development
Dow Chemical Co.

Jack Vanderryn
Agency Director for Energy and Natural Resources
Bureau for Science and Technology
U.S. Agency for International Development

Ronald Wishart
Vice President for Public Affairs
Union Carbide Corp.

James Wolf
Executive Director
Alliance to Save Energy

Erle Young (retired)
Vice President of Environment and Energy
Environmental and Energy Department
American Iron and Steel Institute

Advisory Group on Energy Supply

Stanley R. Bull
Director, Solar Fuels Research Division
Solar Energy Research Institute

William Chandler
Director, Advanced International Studies Unit
Battelle, Pacific Northwest Laboratories

David Choengold
Bureau Director, Systems Planning
Wisconsin Public Service Commission

Joel Darmstadter
Senior Associate
Resources for the Future

William Fulkerson
Director, Energy Division
Oak Ridge National Laboratory

Michael German
Senior Vice President
American Gas Association

Connie Holmes
Senior Vice President for Policy Analysis
National Coal Association

Don Kash
Director
Science and Public Policy Program
University of Oklahoma, Norman

Daniel Lashof
Environmental Scientist
Natural Resources Defense Council

Doug McDonald
Economist
American Petroleum Institute

Joan Ogden
Research Professor
Center for Environmental and Energy Studies
Princeton University

Rajat Sen
Professional Senior Scientist
Battelle, Pacific Northwest Laboratories

Fred Sissine
Analyst, Science and Technology
Congressional Research Service
The Library of Congress

Angelo Skalafuris
President
Modular Cogeneration Corp.

Jim Sullivan
Director, Office of Energy
Bureau for Science and Technology
U.S. Agency for International Development

Alvin M. Weinberg
Distinguished Fellow
Institute for Energy Analysis

Chris Whipple
Manager, Risk Communication
Electric Power Research Institute

Robert H. Williams
Research Professor
Center for Environmental and Energy Studies
Princeton University

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory group members. The groups do not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

Advisory Group on Developing Countries

Robert H. Annan
Staff Director
Committee on Renewable Energy, Commerce and Trade
U.S. Department of Energy

Mark Bernstein
Director
Center for Energy and the Environment
University of Pennsylvania

James H. Caldwell
Independent Consultant

David Curry
Acting Director
Office of Regional and Resources Policy
U.S. Department of the Treasury

Ghazi Darkazalli
Vice President of Photovoltaics
Spire Corp.

Robert Ford
Foreign Affairs Officer
Office of Global Change
U.S. Department of State

Les Garden
International Trade Specialist for Renewable Energy
U.S. Department of Commerce

Michael Greene
Associate Director
Board on Science and Technology in Development
National Academy of Sciences

Erik Helland-Hansen
Principal Technical Advisor
Bureau of Program Policy and Evaluation
United Nations Development Programme

David Jhirad
Senior Energy Advisor
Office of Energy
U.S. Agency for International Development

Linda Ladis
Director of Programs
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International Energy Studies
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Office of Global Change
U.S. Department of State

Janice Mazer
Major Projects Officer
U.S. Department of Commerce

Mohan Munasinghe
Division Chief
Brazil Energy and Infrastructure
Operations Division
World Bank

D. Lou Peoples
Vice President & Manager of Marketing
and Strategy
Bechtel Power Corp.

Paul Schwengels
Senior Analyst
Air Economics Branch
U.S. Environmental Protection Agency

Joseph Sedlak
Director of Domestic Programs
Volunteers in Technical Assistance

James Sullivan
Director, Office of Energy
Bureau for Science and Technology
U.S. Agency for International Development

Franklin Tugwell
Project Director, Biomass Energy
Winrock International Institute for Agricultural
Development

Jack Vanderryn
Director, Energy and Natural Resources
Bureau for Science and Technology
U.S. Agency for International Development

Frank Vukmanic
Director, Office of Multilateral Development Banks
U.S. Department of the Treasury

Timothy Weiskel
Warren Weaver Fellow
Rockefeller Foundation

Gerald T. West
Vice President for Development
Overseas Private Investment Corporation

Thomas Wilbanks
Corporate Fellow and Senior Planner
Oak Ridge National Laboratory

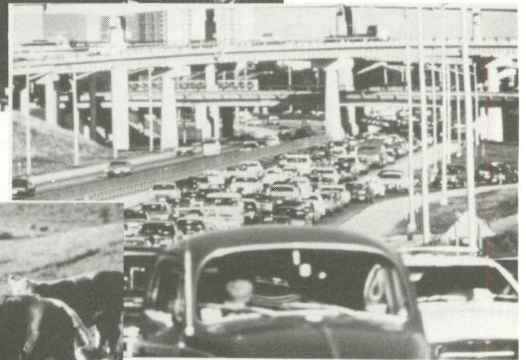
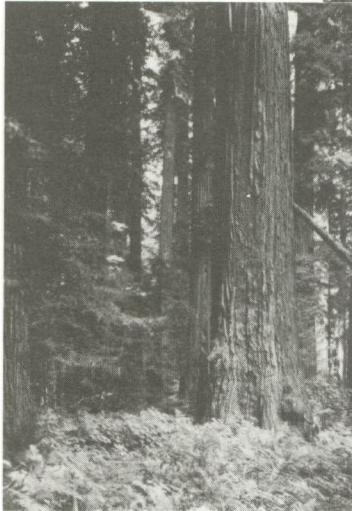
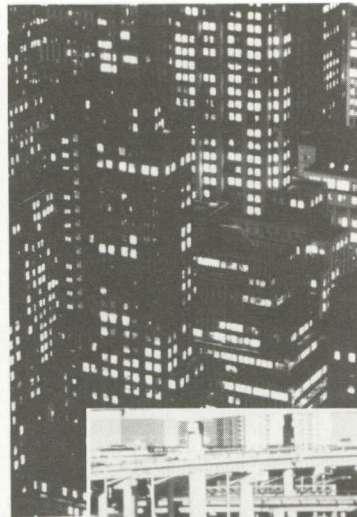
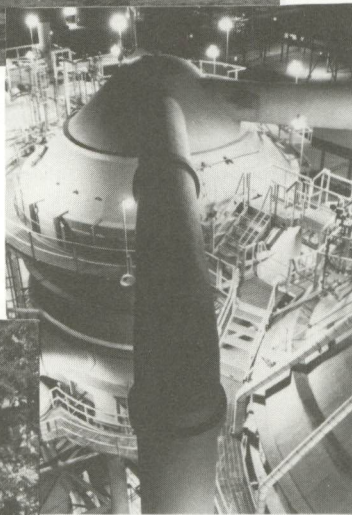
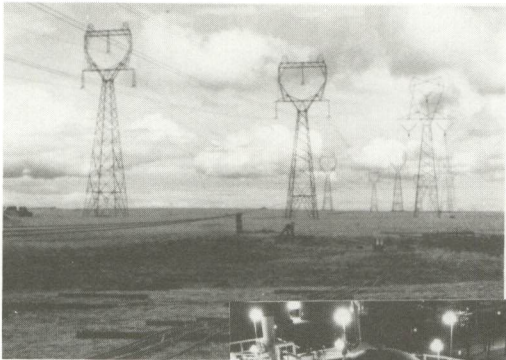
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Export-Import Bank

Advisory Group on Transportation

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Vice President
Science Applications International Corp.
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Director, Office of Energy Research
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Conservation and Renewable Energy Program
Oak Ridge National Laboratory
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Battelle, Pacific Northwest Laboratories
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Center for Auto Safety
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Energy Conservation Coalition
Helen Kahn (retired)
Formerly with *Automotive News*
Richard L. Klimisch
Executive Director, Environmental Activities Staff
General Motors Technical Center

David Kulp
Manager
Fuel Economy Planning and Compliance
Ford Motor Co.
Robert Maxwell
Director, Certification Division
U.S. Environmental Protection Agency
Barry McNutt
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U.S. Department of Energy
Harriet Parcells
Transportation Associate
National Association of Railroad Passengers
Marc Ross
Professor
Physics Department
University of Michigan
Maxine Savitz
Director
Garrett Ceramic Components
Jim Scott
Director, 2020 Project
National Academy of Sciences

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CLIMATE CHANGE AND GREENHOUSE GASES

The first photographs from space brought home the fact that Earth is an integrated and isolated system. Concern that human impacts could be changing the equilibrium of this system grew in the 1970s as theories about ozone depletion and the "greenhouse effect" developed. The concept of the Earth changing over various time scales was not new: solar and astronomical cycles, the waxing and waning of ice ages, and seasonal changes have long been recognized. What was new was the realization that humans can have a lasting and far-reaching impact on Earth's natural fluctuations and cycles.

Potential human impacts on climate are linked to the globally increasing emission of "greenhouse gases"¹ through activities such as burning fossil fuels (coal, oil, natural gas); deforestation; fertilizing croplands; and heating, air-conditioning, and lighting buildings. Greenhouse gases, like other atmospheric gases, allow sunlight to reach and warm the Earth's surface; unlike other atmospheric gases, however, they trap much of the heat and keep it from escaping back into space. Such gases, therefore, aid in warming the surface of the Earth. Some of them—the chlorofluorocarbons (CFCs) and halons—also react with sunlight in the upper atmosphere to destroy the ozone layer around the Earth. In industrialized countries, greenhouse gas emissions are primarily related to energy use; with only 20 percent of the world's population, these countries account for 75 percent of annual energy use. In developing countries, current greenhouse gas emissions are tied primarily to changes in land use practices (e.g., deforestation).

We cannot yet predict the magnitude of climatic effects from greenhouse gas emissions with accuracy. But it is clear that the decision to limit

emissions cannot await the time when the full impacts are evident. The lag time between emission of the gases and their full impact is on the order of decades to centuries;² so too is the time needed to reverse any effects. Today's emissions thus commit the planet to changes well into the 21st century. And the lag times between identification of policy options, legislation of controls, and actual implementation can also be considerable. For example, the recent reauthorization of the Clean Air Act took 10 years; implementation of the Act will begin now and continue over the next 10 to 20 years.

Among individual countries, the United States is the leading contributor of greenhouse gases. With 5 percent of the world's population, the United States accounts for about 20 percent of the world's warming commitment (ref. 56; see figure 1-1a). U.S. CO₂ emissions (20 percent of the global total) originate almost exclusively from fossil fuel combustion. Anthropogenic sources of methane in the United States account for about 6 percent of global emissions from all sources; among the anthropogenic sources, landfills, coal mining, and domestic animals account for most of the U.S. total (2, 24). The United States also consumes between 20 and 30 percent of the world's CFC-11 and CFC-12, the two most damaging chlorofluorocarbons in terms of global warming. Roughly 60 to 70 percent of these CFCs are used in air-conditioning or in the production of thermal insulation; these gases are scheduled to be phased out by the year 2000 under the revised Montreal Protocol. U.S. nitrous oxide emissions (roughly 15 to 20 percent of the manmade global total; refs. 6, 24) originate primarily from fertilizer breakdown and high-temperature fossil-fuel combustion. Greenhouse gas emissions are closely entwined in the United States with energy use; currently, America uses about 15 times more energy per person than does the typical developing country.

¹The main greenhouse gases are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and chlorofluorocarbons (CFCs). The increase in these gases over natural levels is largely due to actions of humankind; CO₂ levels are rising in the atmosphere at a rate 30 to 100 times faster than observed in the climatic record; CH₄ concentrations are increasing 400 times faster than historically. Most scientists anticipate the global average temperature will increase 2 to 8 °F over the next century if current emission trends continue. Changes in weather, wind and ocean circulation patterns, and sea level are expected, leading to unpredictable changes in agriculture, forests, and human settlements.

²The atmospheric lifetime of CO₂ is 50 to 200 years; N₂O, about 150 years; CFCs and halons, from 60 to 400 years; and CH₄, 10 years. CFC replacements allowed under the Montreal Protocol for the next several decades have lifetimes of less than 40 years.

Box 1-A—The OTA Study in Context

The six congressional committees requesting this assessment asked OTA to focus on a very specific question: **“Can the United States reduce carbon dioxide emissions in the near term?”**

Changing by Degrees does not examine in depth many equally difficult questions such as the science of climate change, the uncertainties and state of atmospheric modeling, or the projected ecological effects of global warming. Rather, most of OTA's resources have been devoted to analyzing technical options to decrease CO₂, although methane, nitrous oxide, and chlorofluorocarbon (CFC) emissions are addressed wherever possible. At the time of their request, the congressional committees were well aware of ongoing international efforts to phase out CFCs and halons; since OTA's study began, successful negotiations have been completed.

To answer the question Congress posed, OTA focuses specifically on potential emissions reductions in the next 25 years. The analysis is structured around six key sectors of the U.S. economy: Buildings, Transportation, Manufacturing, Energy Supply, Forestry, and Food. To the extent possible, the report quantifies the potential for emissions reduction within each sector—areas where gains in efficiency, product substitution, conservation, or other technical options can ameliorate increases in CO₂ and other greenhouse gases. A selection of policy options that appear to offer the most promise for achieving these reductions in the United States is presented. OTA was charged to look abroad as well, so the special needs of Eastern Europe, the U.S.S.R., and developing countries—with respect to both energy and natural resource issues—are also addressed.

In our detailed analysis of potential emissions reductions for the United States, we consider an extensive suite of technical options. For example, we estimate the potential increments of CO₂ reduction from electric utility fuel switching, possible improvements in automobile efficiency, changes in commercial building construction, more efficient manufacturing processes, etc. Most of the options relate to decreasing emissions, although some, such as reforestation, involve recapturing gases already emitted to the atmosphere.

The assessment lays out three paths: a Base case (“business as usual”), a Moderate (essentially “no-cost”) case, and a Tough case. Only the last fulfills the congressional request and reduces future CO₂ emissions—to a level in 2015 that is 20 to 35 percent lower than today. Some will argue that our estimates of emissions reductions are both politically unattainable and costly. Others will decry a 20- to 35-percent reduction as not being nearly enough; the Intergovernmental Panel on Climate Change and the U.S. Environmental Protection Agency recently estimated that the world must reduce CO₂ emissions by at least 50 to 80 percent to stabilize the atmosphere. Congress' request that we work within a 25-year timeframe in the study proved to be a two-edged analytic sword. It forced OTA to take a close look at where U.S. CO₂ emissions were heading without policy intervention. But, 25 years also is too short a period to include a scenario in which fossil fuels are supplanted with such nonfossil fuel sources as renewable and improved nuclear energy sources.

Indeed, the United States described 25 years hence in this report does not sound fundamentally different from what we know today. However, an underlying theme in OTA's report is that a strong R&D effort is pivotal to bringing non-CO₂ (i.e., nonfossil fuel) sources to commercialization as quickly as possible, even as all sectors of the economy move to use more efficient equipment and decrease energy consumption. If long-term R&D is geared to that purpose, then new nonfossil supply technologies can start to replace existing powerplants and equipment early in the next century.

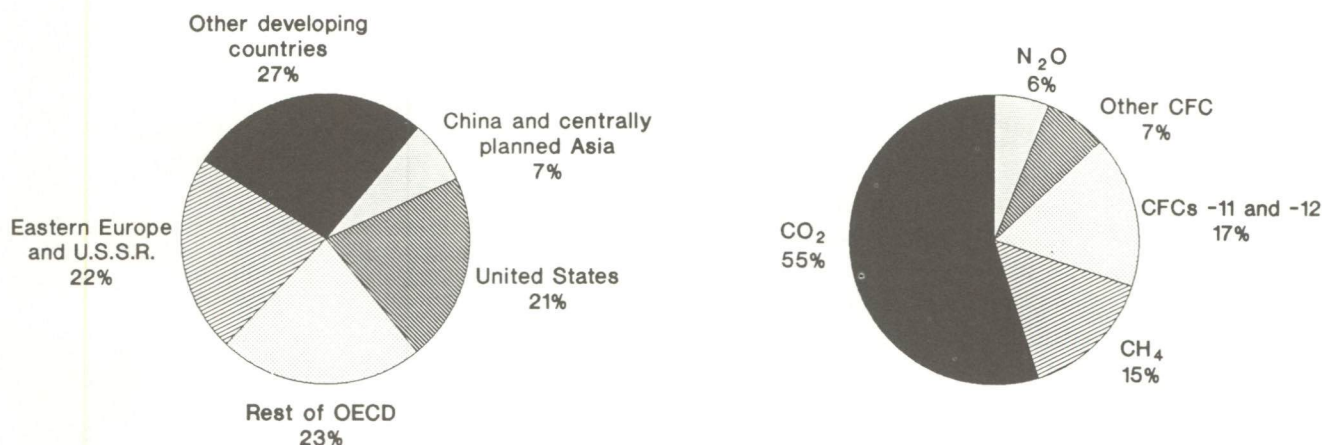
Many of the technical options evaluated here are worth pursuing for other reasons in addition to climate change, because they address other important U.S. goals such as energy security, local environmental quality, and economic competitiveness. They can reduce emissions in the short-term, reduce total energy demand, and serve to bridge the U.S. economy from a fossil-fuel age to a nonfossil future.

The warming commitment or “radiative forcing” caused by the different greenhouse gases is not equal. It depends on the absorbing characteristics, concentration in the atmosphere, and the lifetime of each gas. Although the other gases are more potent on a per molecule basis, currently CO₂ accounts for an estimated 55 percent of the commitment to global warming. This is largely due to the fact that so much CO₂ has been emitted worldwide (6 billion metric

tons of carbon in 1988) as to swamp the higher radiative forcings per unit of the other gases (24). Still, CFCs are responsible for 24 percent of the current commitment to global warming; CH₄ is responsible for 15 percent and N₂O for 6 percent (see figure 1-1b).

Recently, public interest and concern over global changes intensified with the discovery of the annual ozone hole over Antarctica, thinning ozone over the

Figure 1-1—Greenhouse Gas Emissions in 1985, by Region, and the Contribution of Each Greenhouse Gas to Global Warming in the 1980s



NOTE: Figure at left shows the share of greenhouse gas emissions by region, weighted by their contribution to radiative forcing between 1980 and 1990. It includes all greenhouse gases and CO₂ from deforestation and fossil fuel use. Estimates for CO₂ emissions from deforestation range from less than 10 to about 30 percent of total CO₂. If the upper range proves to be correct, developing countries' shares would be larger. Figure at right shows the contribution of each of the manmade greenhouse gases to the change in radiative forcing from 1980 to 1990. The contribution from urban ozone may also be significant, but cannot be quantified at present.

SOURCES: Figure at left: adapted from U.S. Environmental Protection Agency, 1990. Figure at right: Intergovernmental Panel on Climate Change, *Scientific Assessment of Climate Change*, Summary and Report, World Meteorological Organization/U.N. Environment Program (Cambridge, MA: Cambridge University Press, 1990).

Arctic, the severe drought of 1988, and recent abnormal weather patterns in Europe. International concern was demonstrated by the recent rapid renegotiation of the Montreal Protocol to completely phase out CFCs and assist developing countries in achieving that goal. Many industrialized countries, principally in Europe, have further called for a 20-percent reduction in CO₂ emissions from the developed world by 2000 or shortly thereafter; several have pledged to freeze or reduce emissions whether or not the rest of the world participates.

Meanwhile, there is debate here as to whether and when a freeze or a 20-percent reduction in U.S. greenhouse gas emissions could be achieved in the near-term. A 20-percent reduction in U.S. CO₂ emissions would represent a 3-percent decline in current worldwide emissions of CO₂ and less than a 2-percent decline in current worldwide emissions of all greenhouse gases. More importantly, however, even if a 20-percent cut by all developed Nations could be achieved, it would not be enough to stabilize the atmosphere at today's level, let alone to reduce greenhouse gases to pre-industrial levels. To stabilize the atmosphere, the Intergovernmental Panel on Climate Change (24) and the Environmental Protection Agency (EPA) (56) suggest, would require much more—up to an 80-percent global reduction in CO₂ emissions from current

levels as well as significant reductions in the other greenhouse gases. To achieve this under the combined pressures of economic and population growth, nonfossil fuel technologies such as solar or nuclear power would be needed to replace much of today's fossil fuel use.

Energy conservation is the logical first step for the United States if it wishes to reduce its own CO₂ emissions below present levels over the next 25 years. For comparison, if no actions are taken, emissions of CO₂ will likely rise 50 percent during the next quarter century. Under a set of modest policies designed to encourage people to choose technologies that are cost-effective, emissions of CO₂ probably will rise about 15 percent over the next 25 years. This policy package is labeled OTA's "Moderate" scenario.

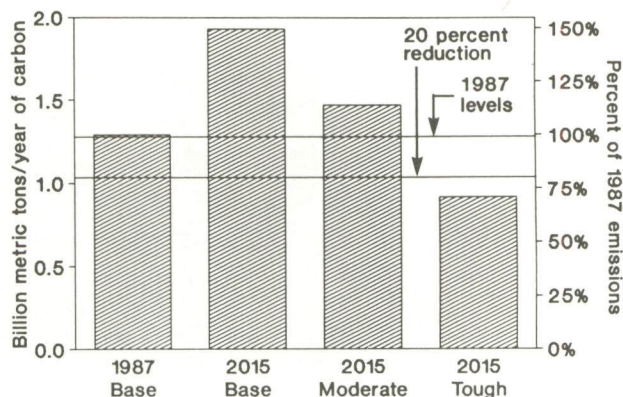
OTA also identified an energy conservation, energy-supply, and forest-management package that can achieve a 20- to 35-percent emissions reduction. This package is labeled OTA's "Tough" scenario. While difficult to achieve, major technological breakthroughs are not needed. Existing equipment would not have to be instantly scrapped and replaced with untested prototypes. The requisite energy-related technologies are either already available or are demonstrated and close to commercialization

today. Most of the forestry-related practices also are proven and already commercialized. OTA's Tough scenario thus does not represent "maximum technical potential." Although it could be argued, for example, that there is a "technical potential" for a massive return to nuclear power by 2015, we assume that this is not feasible for the United States, given lead times and current public concerns. Likewise, we assume that a massive penetration of solar-based electricity generation will not take place by then. Nor will most people be driving 80 mile per gallon (mpg) cars, although prototypes are available today. In each of these cases, though, increased research, development, and demonstration (RD&D) could bring substantial benefits within a half-century.

In the OTA analysis of energy-related activities, only those technical options that would result in CO₂ emissions reductions without loss of comfort or convenience were examined. If implemented, the energy conservation options discussed in our Moderate scenario would likely save consumers money over the lifetime of, for example, an energy-using appliance, given today's energy costs. Greater reductions are quite feasible, as our Tough scenario shows, with technologies that are either technically challenging or more expensive. Even greater reductions are possible if consumers can be persuaded to forego some amenity or comfort;³ however, because many such actions are reversible, they may not continue if energy prices drop and so are not considered here.

U.S. carbon dioxide emissions in 1987 expressed as carbon equivalents⁴ were about 1.3 billion metric tons per year (see figure 1-2). OTA projects that under "business-as-usual" conditions (i.e., our Base case) emissions in 2015 will rise to 1.9 billion metric tons per year. In order to reduce emission levels 20 percent below 1987 levels by 2015 (i.e., to about 1.0 billion metric tons), we must not only attain zero growth over the 1987 level, but must also trim that level by an additional 0.3 billion metric tons. As figure 1-2 shows, a 20-percent emissions reduction is much more than OTA's Moderate scenario but less than its Tough scenario.

Figure 1-2—Summary of OTA's Analysis of Carbon Emissions With and Without "Moderate" and "Tough" Controls



SOURCE: Office of Technology Assessment, 1991.

During the 1970s the extraordinary freeze in energy consumption—while the Gross National Product (GNP) grew 35 percent—was about two-thirds due to increases in energy efficiency and one-third due to structural change⁵ in the economy. Investments in more efficient technologies were facilitated by higher energy prices and the regulatory climate. We already have shown our ability as a Nation to change our energy consumption patterns.

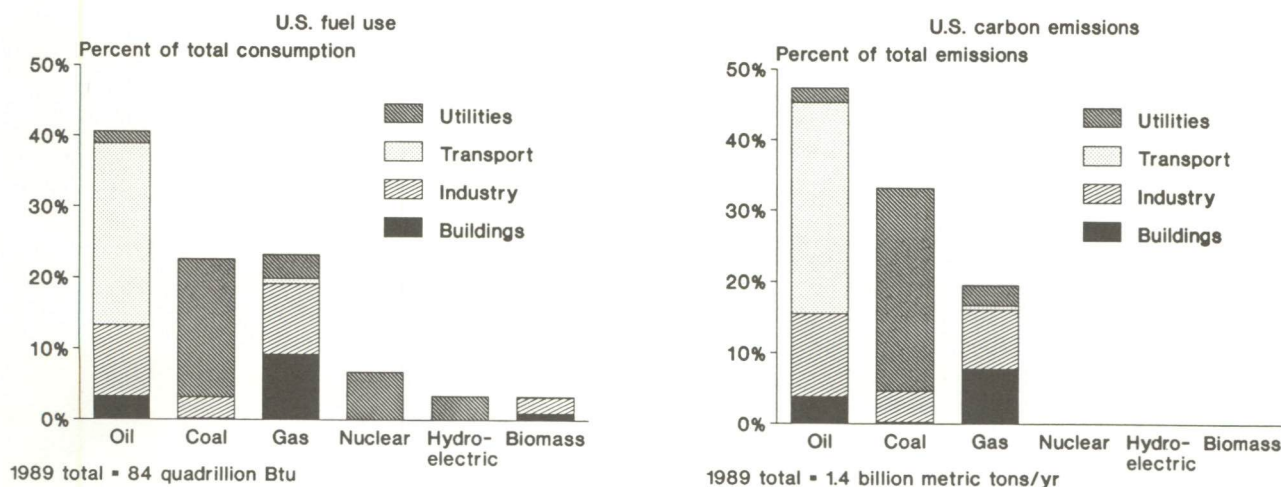
The Nation's track record gives us confidence that such improvements could continue to be achieved, especially if energy prices were to significantly rise again. To achieve lasting reductions in energy consumption, government signals (e.g., pricing and regulatory policies) need to be consistent and reinforcing. Otherwise we are likely to see reversals—as in the 1980s, when energy prices decreased and U.S. fossil fuel consumption started climbing again. For example, higher gasoline prices in the 1970s and early 1980s led to increased purchases of fuel-efficient automobiles. As gasoline prices fell and long-term energy problems were discounted by national leaders, car buyers shifted their attention away from efficiency toward higher luxury and power. Similarly, Federal R&D funding for renewable technology plummeted 90 percent (in constant dollars), from \$1.3 billion in 1980 to \$0.14 billion in

³The U.S. Department of Energy (DOE) found that of an 18-percent reduction in residential energy use between 1972 and 1984, one-third was due to behavioral changes (53).

⁴U.S. CO₂ emissions were 4.7 billion metric tons. For the purposes of this report, all emissions are shown as weight of carbon. To convert to CO₂ equivalent, multiply the weight of carbon by 3.67.

⁵I.e., declines in energy-intensive industry and increases in the service sector. For further details see ref. 47.

Figure 1-3—U.S. Energy Consumption and Associated Carbon Emissions in 1989



NOTE: Emission estimates in the right-hand figure calculated by multiplying fuel use (from left-hand figure) by fossil-fuel carbon emission factors. Coal, 55 to 60 lbs C/mmBtu; oil, 45 lbs C/mmBtu; gas, 32 lbs C/mmBtu. Wood emissions are similar to coal; however in the United States, wood is currently regrown, so we show no net emissions for biomass.

SOURCES: Office of Technology Assessment, 1991, using DOE, 1990.

1990 (see figure 1-6 below). The United States has recently become a net importer of solar thermal and wind systems after dominating the market in the mid-1980s.

A variety of policy interventions will be required to reduce CO₂ emissions 20 to 35 percent below current levels by the year 2015. These could include regulatory "push" and market "pull" mechanisms to provide maximum encouragement and flexibility. They could affect both energy supply and demand and forestry and agricultural practices. Without an increase in and refocusing of current Federal initiatives—including performance standards, incentive programs, energy taxes, and RD&D activities—the use of greenhouse gas reducing technologies is unlikely to increase greatly in the next few decades.

Many of the measures discussed in this study will have ancillary environmental benefits, including abating acid rain, urban smog, ozone depletion in the stratosphere, and groundwater contamination. Decreasing oil use—primarily affecting the transportation sector—will reduce our dependence on foreign oil. Developing and producing renewable energy technologies with worldwide applicability may strengthen U.S. trade markets and our competi-

tiveness abroad. Given that about a dozen industrialized countries⁶ have officially pledged to stabilize or reduce CO₂ emissions by 2005, and that energy demand in rapidly growing, developing countries must increase, burgeoning markets for efficient and lower CO₂-emitting technologies are likely. The United States, as the world's largest producer of greenhouse gases, has an opportunity both to set a good example and be in the forefront of developing new markets for the associated technologies and products.

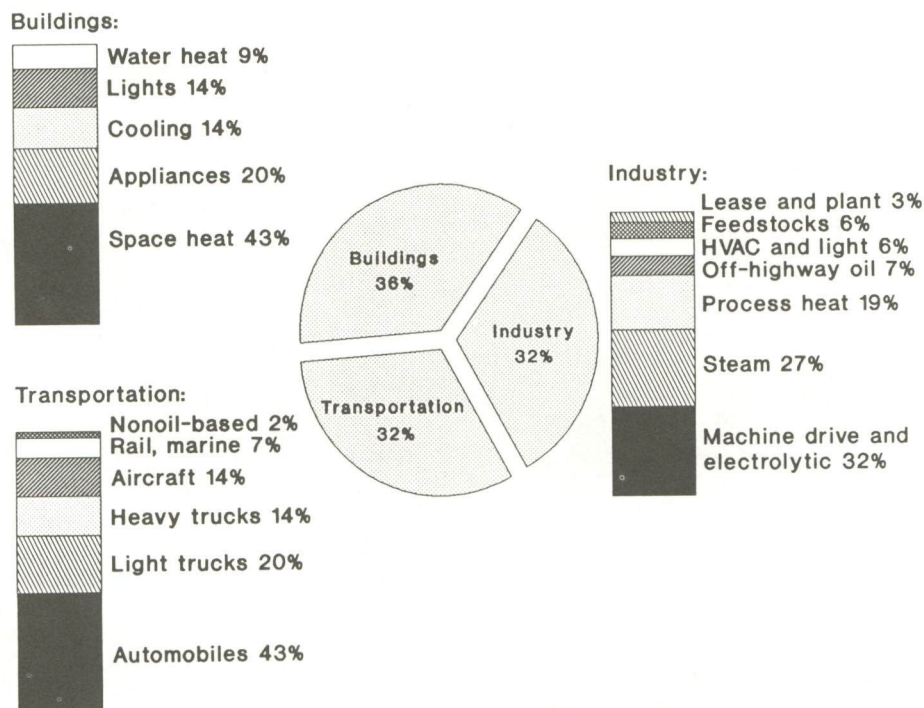
U.S. SECTORAL ANALYSES AND PROJECTIONS OF CO₂ EMISSIONS

Current Emissions

Total U.S. energy use has risen since 1987, the year OTA's modeling effort begins. In 1989, energy use was about 84 quads (quadrillion British thermal units). As shown in figure 1-3a, in 1989 oil accounted for about 40 percent, coal and gas each provided about 23 percent, nuclear power provided 7 percent, and hydroelectric power and biomass each contributed about 3 to 4 percent of energy use.⁷

⁶As of January 1991, Austria, Australia, Canada, Denmark, France, Germany, Italy, Japan, The Netherlands, New Zealand, Norway, Sweden, United Kingdom. Some of these countries' policies are still subject to change.

⁷Data for 1989 energy consumption are from ref. 54.

Figure 1-4—1987 U.S. CO₂ Emissions by Sector

NOTE: Total carbon emissions from all three sectors equaled about 1.3 billion metric tons in 1987. Emissions have continued to increase since then.

SOURCE: Office of Technology Assessment, 1991.

About two-thirds of the total energy was used directly as fuel in “end uses,” for example as gasoline to run our cars and natural gas to heat our homes. Another 35 percent was used to generate electricity; well over half of that electricity was generated from coal.

Carbon dioxide emissions (as carbon) from energy use in the United States in 1989 totaled about 1.4 billion metric tons (this is up from 1.3 billion metric tons in 1987), about 20 percent of the world total. As shown in figure 1-3b, oil accounted for about 48 percent of carbon emissions, coal about 34 percent, and natural gas about 18 percent. One-third of the energy was used to generate electricity. Oil dominates direct uses; coal dominates electricity generation. Coal and wood contain the highest concentrations of carbon per unit energy—commonly about 55 to 60 pounds of carbon per million Btu (lbs C/mmBtu). Natural gas has the lowest concentrations (32 lbs C/mmBtu) and petroleum is intermediate (45 lbs C/mmBtu).

When the emissions from the generation of electricity are allocated to the sector in which the electricity is used, total emissions from energy use are roughly equal in the buildings, transportation, and industrial sectors. Figure 1-4 displays emissions by sector, as well as the major components within each sector. We have detailed estimates of how energy was used in 1987, the reference year for our model. For that year, 36 percent of carbon emissions were from the buildings sector—about 20 percent from activities within our homes and apartments and 16 percent from energy use in commercial buildings.⁸ Another 32 percent of emissions are transportation related and 32 percent come from industry.

Future Emissions Scenarios

For the energy-related sectors, OTA projected future CO₂ emissions under a “business as usual” scenario—our baseline or “Base” case. Two scenarios were then modeled, based on “Moderate” and “Tough” technical measures respectively (see

⁸Of the 36 percent of total CO₂ emissions coming from the buildings sector, one-third is from fossil fuels (i.e., oil and gas) burned directly within residential and commercial buildings; two-thirds come indirectly as a result of the generation of electricity used in buildings.

box 1-B for a description of the model). Moderate measures typically require some initial capital investment but later save money through future fuel savings; in most cases savings more than compensate for initial costs. None of the measures are difficult to achieve technically, though inducing consumers to use them may not be easy.

The “Tough” measures would lower energy demand even further, but in many cases at a higher cost for the same level of convenience and comfort. All of the Tough measures analyzed are technically feasible, but most are not based on the best available prototypes or practices; OTA made judgments about what will be feasible for widespread use. Fully implementing the Tough measures would be challenging—politically, logistically, and perhaps economically.

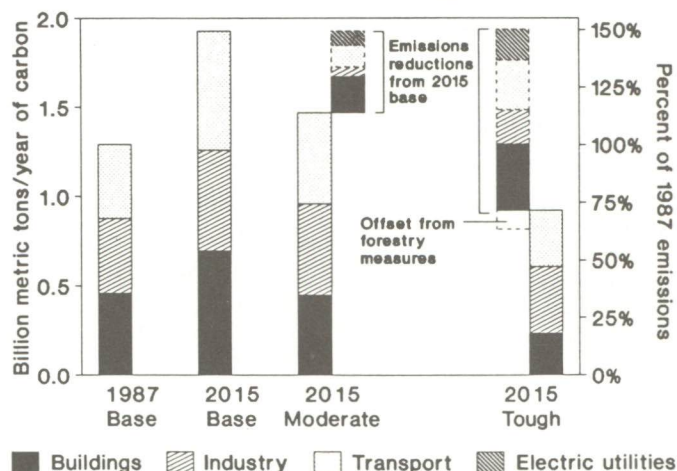
The model only included energy-related sectors. For the forestry sector, OTA independently evaluated Moderate and Tough measures; these were chosen by the same criteria as measures in the model (i.e., difficulty and cost) and estimates of CO₂ uptake over time were calculated. Data were not sufficient to calculate potential emissions reductions from the food sector.

Overall Modeling Results

Based on the OTA energy modeling analysis, under current trends and regulations carbon emissions by 2015 will be close to 50 percent greater than today’s level—almost 1.9 billion metric tons per year (see figure 1-5). This Base case projection assumes that some efficiency improvements will occur even in the absence of new legislation. For example, by then we assume new homes will require 15 percent less heating, recently adopted appliance standards will have taken effect, and new cars will average close to 37 mpg.

By adopting all Moderate measures that lower energy demand, CO₂ emissions in 2015 could be held to about a 22-percent increase over 1987 levels. The emissions savings achieved by the Moderate measures are shown for each demand sector (buildings, transportation, industry) as well as for electricity supply in figure 1-5. Changes in the fuel mix used to generate electricity can lower emissions an additional 6 to 7 percent. The Moderate forestry

Figure 1-5—Carbon Emissions Under the Base Case, Moderate, and Tough Scenarios



NOTE: The boxes outlined with dashed lines represent the reductions in carbon emissions associated with control measures applied in each of the three demand-side sectors (i.e., buildings, industry, and transportation) and electricity supply (electric utilities); additional carbon offsets afforded by forestry measures are also shown. The boxes outlined with solid lines represent total emissions from each demand-side sector. For the solid boxes, emissions associated with electricity generation have been allocated to the three demand-side sectors.

SOURCE: Office of Technology Assessment, 1991.

measures provide about a 0.2-percent offset in carbon emissions by 2015. All Moderate measures together hold emissions to 15 percent above 1987 levels.

Finally, OTA’s Tough scenario could lower net emissions by 2015 (excluding offsets from forestry measures) to 29 percent below 1987 levels—i.e., to about 0.9 billion metric tons per year. This is about half of our Base case forecast for 2015. Tough forestry measures could reduce emissions another 7 percent. The detailed emissions reductions estimated for the Tough scenario analysis are shown in table 1-1, by individual measures within sectors.

Costs

While we think the Moderate scenario is achievable at a net savings,⁹ nonetheless substantial shifts in the economy would have to occur. For example, energy expenditures would be 15 percent lower than they would be otherwise, but the cost of appliances, cars, and houses would be higher.

⁹We believe that overall savings are possible because, on balance, fuel savings (assuming projected 2015 prices) will exceed annual capital and operating costs.

Box 1-B—The OTA CO₂ Emissions Reduction Model

OTA developed a simple energy accounting model to estimate the effectiveness of various technical options for lowering CO₂ emissions. The model is based on a larger system of energy and economic models used by the Gas Research Institute (GRI) to forecast energy use through 2010 (23)¹. Of all the integrated energy/economic forecasting models available, the GRI approach includes the greatest detail on the demand side for specific technologies. (Other models may contain, for example, estimates of total residential electricity demand, but do not include breakdowns of heating, cooling, refrigerators, freezers, clothes dryers, etc.) With such information, changes in CO₂ emissions can be simulated in detail based on changes in technology.

GRI provided OTA with detailed output from its model simulations of energy use through 2010. We, in turn, built a very much simplified set of models by “modeling” GRI’s detailed output. For example, to estimate the energy demand for heating homes, GRI’s residential sector model starts with the number of existing furnaces, heat pumps, and electric heaters. It then forecasts the number that must be replaced through time (with more efficient technology) based on typical equipment lifetimes. The number of new homes (which, of course, must also be heated) is forecast based on economic conditions. Whether consumers buy gas, oil, or electric heaters is forecast in part based on economics and in part on historical buying habits.

OTA took the GRI forecasts of energy use by each technology category (e.g., gas furnaces) and built a series of simple models that simulate the number and energy efficiency of each technology type through time, based *only* on the GRI detailed output data, rather than the economic decisions that influence the forecast. Note that for two categories—highway vehicles and electric utilities—we felt that the GRI model did not have adequate detail for our needs. For highway vehicles, we used Oak Ridge National Laboratory’s “Alternative Motor Fuel Use Model” (but used GRI’s oil price assumptions for consistency). For electric utilities, we built our own model using detailed data from the U.S. Department of Energy’s Energy Information Administration.

We total all the energy use and CO₂ emissions from each technology and sector. This forms the basis for our Base case forecast that emissions will be approximately 50 percent above today’s level by 2015. In the Base case (business as usual), OTA implicitly assumes GRI’s economic forecast of GNP growth averaging 2.3 percent per year and energy price increases averaging 1.7 percent per year for coal, 3.7 percent per year for oil, and 4.8 percent per year for natural gas over the next two decades. This represents a reasonable future picture barring major changes in energy supply, economic, or regulatory conditions.

Then we estimate the effect of changes in technology (e.g., more efficient gas furnaces than included in the GRI forecast) or policy (e.g., forcing coal-fired plants to retire after 40 years of operation) in two alternative scenarios: “Moderate” and “Tough.” Our model, for the most part, assumes the same level of “services” as the GRI base case. In the alternative scenarios, CO₂ emissions are reduced, for example, by using more efficient furnaces, switching fuel, or insulating houses, but *not* by assuming people keep their homes at lower temperatures in the winter or warmer in the summer like they currently do. In a few cases, most notably the transportation options, all “services” are not identical. For example, one of the measures that we include is to reinstate a 55 mph speed limit. Under our most aggressive scenario, we assume that cars will be somewhat smaller than they are today (for either economic or regulatory reasons). Both of these include some loss of convenience to consumers.

¹The GRI modeling system has as its core the U.S. Energy Model, developed by Data Resources, Inc. (DRI). The model includes four submodels: the industrial sector, residential sector, commercial sector, and electric utilities. Economic projections, which drive the Energy Model, come from the DRI Macroeconomic Model of the U.S. economy. Additional inputs are generated from the Industrial Sector Technology Use Model, developed by Energy and Environmental Analysis, Inc.; the GRI Hydrocarbon Supply Model; and the RDI Coal Model, developed by Resource Data International.

Many of the Tough scenario measures entail costs in excess of projected fuel savings; others are cost effective over their lifetime but are difficult to implement. A rough estimate of the cost range for the Tough scenario is a savings of \$20 billion to a cost of about \$150 billion per year (in 1987 dollars)

by 2015, after subtracting fuel savings (assuming forecasted 2015 fuel prices).¹⁰ This range is equal to savings of a few tenths of a percent to a cost up to 1.8 percent of the Gross National Product (GNP) projected for 2015. For comparison, all environmental compliance costs today are about 1.5 percent of

¹⁰For example, we assume that oil prices by 2015 will be about \$50 per barrel.

Table 1-1—Measures To Lower U.S. Carbon Emissions
(expressed as percentage of 1987 total emissions)^a

	Reductions in 2015			Reductions in 2015	
	Moderate (in percent)	Tough (in percent)		Moderate (in percent)	Tough (in percent)
DEMAND-SIDE MEASURES			Industry		
Residential buildings			New investments:		
New investments:			Efficient motors	1.2	3.7 to 4.0
Shell efficiency	1.3	2.0	Lighting	0.5	0.7 to 0.8
Heating and cooling equipment ...	0.1	0.4 to 0.6	Process change, top 4		
Water heaters and appliances ...	1.2	1.5 to 2.3	industries	3.0	8.2
O&M, retrofits:			Fuel switch to gas	0.0	2.4 to 2.7
Shell efficiency	0.8	0.9	Cogeneration	0.8	5.2 to 5.8
Lights	0.6	0.8	O&M, retrofits:		
All residential measures together	4	5.6 to 6.6	Housekeeping	1.9	2.0
			Lighting	0.1	0.2
Commercial buildings			All industrial measures together	8	17 to 18
New investments:			ELECTRIC UTILITY SUPPLY-SIDE MEASURES		
Shell efficiency	2.3	4.0	Existing plant measures:		
Heating and cooling equipment ...	1.0	1.2 to 1.9	Improved nuclear utilization	4.1	4.1
Lights	2.1	3.0	Fossil efficiency improvements ...	1.7	1.7
Office equipment	1.6	2.1	Upgraded hydroelectric plants ...	0.5	0.5
Water heaters and appliances ...	0.1	0.1	Natural gas co-firing	—	3.7
Cogeneration	0.2	1.5 to 2.3	New plant measures:		
O&M, retrofits:			No new coal; higher fraction		
Shell efficiency	0.8	0.8	of new nonfossil sources	—	0.0 to 4.7
Lights	0.5	0.5	CO ₂ emission rate standards	0.4	0.0 to 0.1
All commercial measures together ...	8.5	13 to 15	All utility supply-side measures		
Transportation			together	6.6	9.9 to 14
New investments:			FORESTRY MEASURES		
New auto efficiency	0.8	3.5 to 3.8	Afforestation:		
New light truck efficiency	0.5	2.5 to 2.7	Conservation Reserve Program ...	0.2	0.2
New heavy truck efficiency	0.4	2.4 to 2.4	Urban trees	—	0.7
Non-highway efficiency	0.5	1.2	Additional tree planting	—	2.3
O&M, retrofits:			Increased timber productivity	—	3.1
Improved public transit	0.2	3.5	Increased use of biomass fuels	—	1.2
Truck inspection & maintenance ..	0.3	0.4	All forestry measures together	0.2	7.5
Traffic flow improvements/ 55 mph speed limit	1.2	1.4			
Ridesharing/parking controls	0.4	1.0			
All transportation measures together	4	14 to 15			

^a1 percent of 1987 emissions = 13 million metric tons C = 0.7 percent of 2015 emissions.

SOURCE: Office of Technology Assessment, 1991.

GNP; direct fossil fuel and electricity consumption purchases account for about 9 percent of GNP.

Other groups have tried to estimate the costs of CO₂ reductions, but with different control scenarios, often a carbon tax. For example, using several short-term econometric models (i.e., analyses that extend only to the year 2000), the Congressional Budget Office (CBO) estimated that a \$100 per ton carbon tax phased in by the year 2000 would hold CO₂ emissions at just about current levels or reduce them to 25 percent below current levels by 2000 (45). By the end of the first decade, GNP would be lowered by about 0.5 to 2.0 percent (about \$40 to \$130 billion per year in 1987 dollars). However,

GNP effects over the first few years of a suddenly instituted policy could be 5 percent or more.

CBO also looked at two longer term econometric models that forecast energy use past 2000, one constructed by the Environmental Protection Agency (EPA) and the other by the Electric Power Research Institute (EPRI). These models' projections for Base case energy use in 2015 are reasonably close to each other and to OTA's Base case and thus offer useful comparisons of reductions and costs. The model used by EPA forecasts that holding emissions to 10 to 15 percent below current levels would lower GNP by about 1 to 1.3 percent by the year 2015. The EPRI model forecasts that holding emissions to 20 percent

below current levels would lower GNP about 3 percent by that year.

The costs associated with any scenario depend on many factors—including the price of fuel projected under Base case conditions. For example, we are assuming the price of crude oil will be \$42 per barrel (in 1987 dollars) by the year 2010 (23) and about \$50 per barrel by 2015.¹¹ Net costs for an emissions reduction scenario would be higher if 2015 fuel prices are lower than projected; for example, if oil prices are \$5 per barrel lower in 2015 than we forecast (and other energy prices remain the same as forecast), costs will be about \$15 billion higher. Similarly, net costs would be lower if energy prices rise more than projected. No quantitative estimates have been made of the ancillary air, water, soil, health, economic, and energy security benefits that result from reducing energy use and associated pollutants.

OPTIONS FOR REDUCING U.S. EMISSIONS

The major options available or likely to be available for reducing CO₂ emissions in the near-term fall into three categories:

1. increasing energy conversion and efficiency in end-use technologies,
2. changing use patterns to conserve energy, and
3. shifting energy supply away from high CO₂-emitting fuels.

Additional options to offset CO₂ emissions are primarily forestry-related or agricultural. If Congress chooses to pursue any of these options, it obviously will also seek to assure continuous economic progress.

When choosing policy options Congress must consider two interdependent components: the universe of possible **technical** (or in some cases, behavioral) changes and the **policy instruments** (e.g., taxes, regulations, financial incentives) available to require or encourage the technical change. One policy option, for example, would be to reduce CO₂ emissions through regulations (i.e., a policy instrument) to require more fuel-efficient autos (i.e., a technical option). An alternative or perhaps complementary policy option would be to use a high

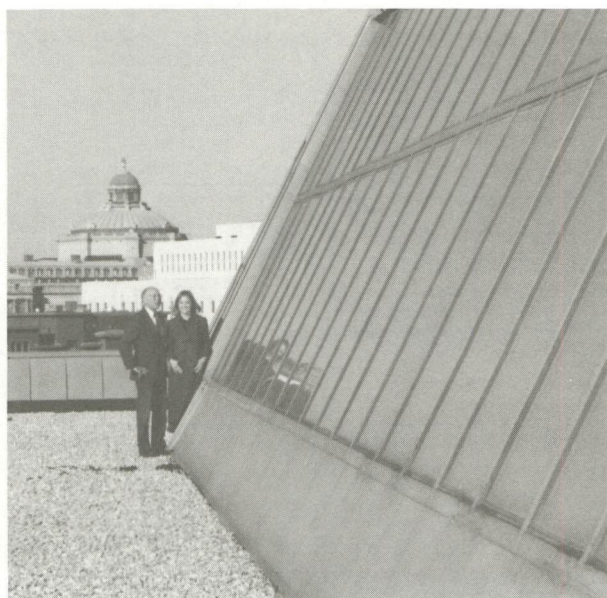


Photo credit: Chip Moore

Solar panels supply all of the hot water and up to 70 percent of the space heating needed for the 80,000-square-foot building in which OTA is housed.

“gas guzzler” tax (i.e., policy instrument) to stimulate purchase of fuel-efficient autos.

Technical Options

This report identifies a range of CO₂-reducing technical options available or likely to be available to the Nation over the next 25 years, and what their contribution might be. There are a large number of technical options to pick from and many targets of opportunity within each sector, as figure 1-4 shows. Significant progress in reducing U.S. CO₂ emissions will require that most of these options be pursued simultaneously.

Presently available energy “supply” options for achieving major CO₂ reductions over the 25-year timeframe of this assessment include: replacing high carbon-emitting fuels (e.g., coal) with lower carbon-emitting fuels (e.g., natural gas); using high-efficiency, electricity-generating technologies (e.g., high-efficiency gas turbines or cogeneration); and using nonfossil fuels.

While nonfossil energy offers the greatest long-term potential for achieving deep cuts in CO₂ emissions, we cannot count on large-scale use of

¹¹For comparison, DOE's Energy Information Administration estimated the price of oil to be \$28 to \$46 per barrel by 2010; the American Gas Association projected \$48 per barrel in 2015.

nonfossil energy sources to replace fossil fuels within 25 years. These sources do not yet offer the performance, costs, or social acceptance needed to fully displace fossil fuels in such a relatively short period of time (42). Only three nonfossil sources are presently being used on a significant scale in the United States: hydroelectric power, biomass, and nuclear light-water reactors (LWRs). Because of a combination of low baseload demand growth, cost, and environmental and social problems, no orders for new LWRs have been initiated in over a decade and there are no plans underway to build new reactors in the United States. Environmental factors set an upper limit on the number of potential new dam sites for hydroelectric facilities and on biomass production.

On the energy "end use" side, the technical options available today are primarily more efficient technologies or changes in energy use patterns. The first requires time and investment, whether for old equipment to be replaced or new equipment to be purchased. Changing energy use can include immediate (but reversible) changes such as fewer miles driven, lights dimmed, etc. In addition to the currently available technical options there is a large menu of additional options that could be developed over time. A diverse suite of energy R&D is ongoing, but what it will make available in the next quarter century depends greatly on Federal funding for demonstration.

Several technical options are available in the forestry sector to provide some offsets of CO₂ emissions. Increasing forest productivity and planting new trees can result in increased carbon storage that offsets fossil-fuel related emissions. Planting short-rotation tree crops for use as biomass fuels can partially replace the use of fossil fuels in some situations. These and other forestry options have attendant uncertainties and difficulties. For example, attempts to increase productivity focus on the timber component of forests (i.e., the commercially valuable portion). However, it is unclear whether increases in timber productivity actually indicate whether or not productivity in the entire forest has increased.

Policy Instruments

Policy instruments are the means government uses to require or encourage a desired technical or behavioral response. Many potential targets exist

within each sector to achieve CO₂ emissions reductions (see figure 1-4). Whatever the CO₂ reduction goal, Congress will have to use a variety of policy instruments to stimulate a diverse set of decisionmakers to use the appropriate fuels, technologies, and forestry and agricultural practices and to adopt energy use patterns that conserve energy.

Identifying the relevant decisionmakers will be critical to selection of appropriate policy instruments. Within the energy system, for example, appliance and lighting use patterns represent the collective decisions of nearly all Americans. In contrast, utility fuel choices are made within a relatively small community of decisionmakers (e.g., utility executives, State regulators, and segments of the financial community).

Certain generalizations nonetheless can provide guidance:

- Decisionmakers generally prefer lower cost options and many individuals prefer low first-cost options over low life-cycle cost options.
- Highly efficient "cutting edge" technologies often have relatively lower life-cycle costs but higher front-end costs.
- Historically, fragmented decisionmaking reinforces the preference for low first costs, especially in the buildings sector—decisions relevant to efficiency are made by developers and builders, not by the occupants who will be paying the energy bills.

A wide range of possible policy instruments could be used to influence decisionmakers. Table 1-2 groups them into six generic categories:

1. taxes;
2. financial incentives;
3. marketable permits;
4. regulations;
5. research, development, and demonstration (RD&D); and
6. information and public education.

Just as there is no single technical option that is a cure-all, many policy instruments will be needed. The synergisms possible among taxation, regulation, incentives, information, and RD&D programs are key to significantly reducing emissions. Taxes, if properly set, can be used to adjust prices to tilt purchase decisions. Regulation (codes and standards) can be used to remove the least efficient equipment, appliances, and buildings from the

Table 1-2—Policy Instruments To Reduce CO₂

	Taxes			Financial incentives			Marketable permits		Regulations		RD & D		Information	
	Energy tax	Carbon tax	Purchase tax	Tax incentive	Low cost loans	Direct payments			Performance standards	Building codes	R&D	Demonstration	Labels/rating	Audits
Commercial buildings														
Thermal integrity	✓	✓	—	✓	✓	✓	—	—	—	✓	✓	✓	✓	✓
Appliance/lighting	✓	✓	✓	✓	—	—	—	—	✓	—	—	—	✓	✓
Usage patterns	✓	✓	—	—	—	—	—	—	—	—	—	—	—	✓
Residential buildings														
Thermal integrity	✓	✓	—	✓	✓	✓	—	—	—	✓	✓	✓	✓	✓
Appliance/lighting	✓	✓	✓	✓	✓	—	—	—	✓	—	—	—	✓	✓
Usage patterns	✓	✓	—	—	—	—	—	—	—	—	—	—	—	✓
Transportation														
Small car/truck efficiency ..	✓	✓	✓	✓	✓	✓	—	—	✓	—	✓	✓	✓	—
Alternate fuels	—	✓	—	✓	✓	✓	—	—	—	✓	✓	✓	—	—
Off highway ^a	—	✓	—	—	—	—	—	—	✓	✓	—	—	—	—
Vehicle miles traveled	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—
Manufacturing														
Efficiency	✓	✓	—	—	—	✓	✓	—	—	—	✓	—	—	✓
Recycling	✓	✓	—	✓	—	—	—	—	—	—	—	—	—	—
Energy supply														
High to low carbon fuels ..	—	✓	—	—	—	✓	✓	—	—	—	✓	—	—	—
Renewable	✓	✓	—	✓	—	—	✓	—	—	—	✓	—	—	—
Cogeneration	✓	✓	—	✓	—	—	✓	—	—	—	—	—	—	—
Efficiency, existing plants ..	✓	✓	—	—	—	—	✓	—	—	—	—	—	—	✓
Forests														
Recycling	—	—	—	✓	—	✓	—	—	✓	—	—	—	✓	—
Increased productivity	—	✓	—	✓	—	✓	—	—	—	—	—	—	—	—
Afforestation	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—
Biomass	✓	✓	—	✓	—	—	—	—	—	—	✓	—	—	—
Food														
Farm inputs	—	✓	—	—	—	✓	—	—	✓	—	—	✓	✓	—
Farm operation & efficiency	—	✓	—	✓	—	✓	—	—	✓	—	✓	—	—	—
Food processing	—	✓	—	—	—	—	—	—	—	—	—	—	—	—

^aHeavy equipment, aircraft.

SOURCE: Office of Technology Assessment, 1991.

market. Incentive and information programs can be used to clarify cost information and help create a market for improved energy performance. Education programs also provide consumers with the knowledge and information needed to make wiser energy choices. Government-sponsored RD&D can help provide producers and consumers with new technical options that can be used to reach national goals, as well as reduce, by cost-sharing, the risk to industry of developing these new options.

Taxes

Taxes offer a way to make high CO₂-emitting technical options more expensive than lower CO₂-emitting options. If Congress so desires, new tax monies could help fund incentive programs, offset the budget deficit, or replace other existing taxes.

Three possibilities include: 1) a general energy tax, 2) a carbon tax, and 3) initial purchase taxes. A general energy tax is levied on the energy (i.e., Btu) content of fuels. A carbon tax is set to reflect the fact that some fuels emit more carbon per unit of energy than do others. Both of these are thus "fuel" taxes. An initial purchase tax is levied on energy-consuming technologies, rather than fuels; the tax would be based on estimates of lifetime energy use or carbon emissions.

The first—a general energy tax—would stimulate greater energy efficiency, regardless of whether energy is derived from fossil or nonfossil fuels. By making all energy more expensive, it would apply pressure to reduce total energy use. On the other hand, a carbon tax would not only stimulate energy efficiency, but also shift the energy system from high carbon-emitting fossil fuels to nonfossil fuels or lower carbon-emitting fuels (e.g., natural gas).

Initial purchase taxes could have effects broadly similar to either an energy or carbon tax, depending on whether they were based on lifetime energy use or carbon emissions. Because consumers are often more concerned with the initial cost of a technology than with "life-cycle" costs (i.e., including fuel costs), purchase taxes can be more effective than either type of fuel tax in many situations. An example of an initial purchase tax is the current "gas guzzler" tax on autos, which was increased in the 1990 Omnibus Budget Reconciliation Act (Public Law 101-508). In a similar fashion, a tax on less efficient appliances or houses could serve to reduce

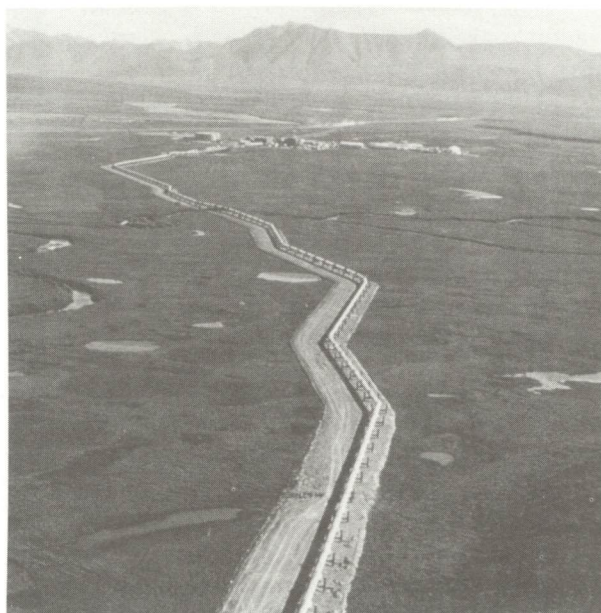


Photo credit: Chevron

The Trans-Alaska pipeline has been in operation since 1977. North Slope oil production is currently declining, and a little less than 2 million barrels of crude oil per day now flow through the 800-mile pipeline. The United States currently uses 17 million barrels of oil each day.

consumer preferences for lower initial costs rather than life-cycle costs.

Energy and carbon taxes have the advantage of affecting all emitters simultaneously, rather than focusing on a few selected technologies. A carbon tax is a particularly effective way of targeting the heaviest economic sanctions against the worst emitters of CO₂. A carbon tax would stimulate greater demand for natural gas relative to other fossil fuels. This, in turn, could drive natural gas prospecting and resource recovery technology development. Over the longer term, it could also motivate development of noncarbon energy sources whereas a straight energy tax would probably not.

Financial Incentives

Through financial incentives (e.g., tax incentives, low cost loans, and direct payment subsidies), the government pays part of the costs of utilizing desirable fuels, technologies, or practices. Tax incentives can be powerful instruments for stimulating desired actions by corporations and individual taxpayers looking for ways to reduce tax liabilities; however, tax incentives have little effect on those who pay low or no taxes.

Low-cost loans either defray some portion of loan interest or eliminate lender risk by insuring against loss. Low-cost loans can be effective policy instruments to stimulate utilization of CO₂-reducing technical options by both individuals and corporations. Direct payments for utilization of CO₂-reducing options (e.g., cash bonus for scrapping an old, fuel-inefficient car) are especially effective in stimulating the use of desired options by low-income or financially strapped decisionmakers.

Marketable Permits

Marketable permits and carbon taxes are closely related. Under a marketable permit system, policymakers fix the amount of carbon that can be emitted. The government then issues the allowed number of permits to emit a given amount of carbon. Permits can be bought and sold by energy users just like fuels. For example, for every 1 million Btu's of coal purchased, the user must also own (or purchase) permits to emit 57 pounds of carbon. To burn 1 million Btu's of natural gas, the user must own or purchase permits to emit 32 pounds of carbon. If demand for energy rises, the price of a carbon permit will rise to reflect the cost of lowering emissions. Some holders of permits will find ways to lower emissions (e.g., purchase more efficient equipment, switch from coal to natural gas) so that they can sell their permits (at a profit) to others. Theoretically, the effective price of fossil fuels will rise just high enough to meet the allowed carbon emission target. Just how high prices will rise, however, is difficult to forecast.

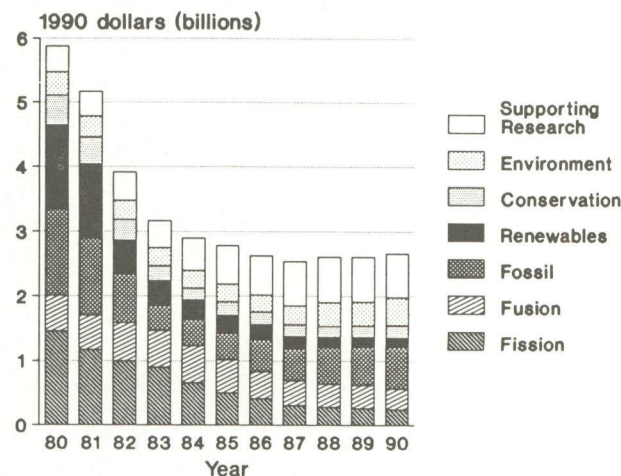
Marketable emission permits is the current U.S. method for enforcing the Montreal Protocol and controlling CFC emissions. A marketable permit system also is the regulatory mechanism for limiting emissions of sulfur dioxide to control acid rain under the new Clean Air Act Amendments (Public Law 101-549).

Marketable permits could be required for all fossil fuel users or only for large users such as electric utilities, factories, and even large commercial installations. Permits could be required for wholesalers who sell gasoline, rather than for individual drivers.

Regulations

Regulations are policy instruments that can eliminate inefficient and/or high CO₂-emitting activities from the market. They can take the form, for example, of performance standards and building

Figure 1-6—Federal Government Funding for Energy Supply R&D, 1980 to 1990



NOTE: The bars represent Federal budget authority for research, development, and technology demonstrations, in 1990 dollars. "Supporting" refers to research in basic energy sciences.

SOURCES: J.P. Holdren, "Energy in Transition," *Scientific American* 263(3):156-163, September 1990, original data compiled from the Office of Management and Budget, *Budget of the United States Government, Fiscal Years 1980 Through 1991* (Washington, DC: U.S. Government Printing Office, 1980 through 1990); Intersociety Working Group/American Association for the Advancement of Science, *Research and Development FY 1980-1991* (Washington, DC: 1980 through 1990); and *Environmental and Energy Study Conference, Weekly Bulletin(s)* and *Special Report(s)* (Washington, DC: several years).

codes. Performance standards can be established for many diverse types of technologies (e.g., lighting standards) and applied nationwide; they are currently used for automobile efficiency and appliance efficiency. Building codes traditionally have been the province of local governments and their effective use depends on enforcement at that level.

Research, Development, and Demonstration (RD&D)

Through RD&D, government can search for and fine-tune technological fixes to the greenhouse gas emissions problem. In fact, climate change can only be effectively addressed over the long-term with the development and worldwide use of better nonfossil energy sources. Government can speed the process of testing and commercializing many energy-supply and end-use technologies. However, only about 5 percent of the \$2.7 billion national budget for energy technology R&D in 1990 was devoted to renewables (including biomass energy) and only 7 percent to energy conservation. Fossil fuels had 25 percent of the research budget, nuclear fusion 12 percent, and nuclear fission 9 percent (see figure 1-6).

Information

Information as a policy instrument has the potential to change the awareness level and perceptions of decisionmakers. Information programs rest on the assumption that if decisionmakers are better informed they will make better decisions. The most common goal of information programs is to stimulate decisionmakers to opt for least cost (life-cycle) savings, as opposed to initial-purchase savings, in their energy decisions. For example, although the most efficient model of an appliance usually costs more initially, energy savings accrue over its useful life. Information can be supplied by Federal, State, or local governments, utility programs (see “Demand-Side Management” below), manufacturers, or non-governmental organizations (NGOs).

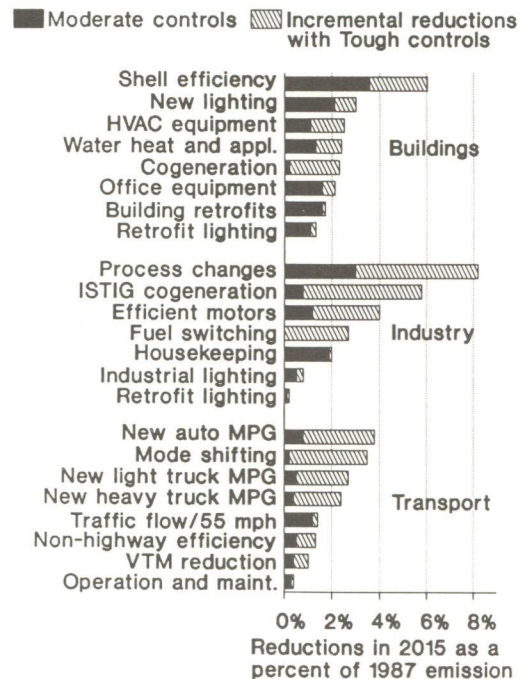
Information can be delivered to all decisionmakers in many ways, for example via label and rating systems and audits. Label and rating systems serve to provide purchasers with a basis for comparing front-end versus life-cycle costs at the time of purchase. Energy audits provide building owners and occupants with information they need when considering whether to purchase, rent, or retrofit alternatives. Energy audits can be effectively coupled with financial incentives to carry out retrofits that provide greater efficiency, and thus reduced CO₂ emissions.

Sectoral Policy Options

Buildings Sector

Figure 1-7 summarizes the emissions reductions possible for each “demand-side” option modeled by OTA under both the Moderate and Tough scenarios. For buildings, improving shell efficiency and lighting are the two technical options with the greatest potential for lowering CO₂ emissions. Under the Base case, OTA assumes that by 2015 new homes and apartments will be designed such that they need about 15 percent less heating and 8 percent less cooling than current new homes. By adopting Moderate shell efficiency measures, such as thicker insulation and better windows, new homes will require an estimated 50 percent less heat and 25 percent less air-conditioning than today’s average new home (27). With Tough measures, homes can be built to require an estimated 85 percent less heat and 45 percent less air-conditioning (20).

Figure 1-7—Demand-Side Measures



NOTE: Reductions presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

As shown in table 1-1, Moderate shell improvements in new residential buildings can reduce U.S. carbon emissions by 1.3 percent of current levels by 2015. By implementing Tough improvements in the North and Moderate ones in the South, reductions of 2 percent in new residential buildings might be achieved. Tough measures for new commercial building shells can achieve reductions equal to 4 percent of 1987 levels by 2015.

Existing homes can also be made more efficient by installing more efficient heating and cooling equipment, insulation, windows, etc. The Base case assumes that existing homes will require 6 percent less heating by 2015 because of replacements and improvements that will happen anyway. Moderate measures boost this to 25 percent by 2015 and Tough measures boost it to 40 percent by 2015 (20). Tough measures in the North and Moderate ones in the South would reduce carbon emissions from existing buildings by 4 percent by 2000, but would have a declining effect thereafter as many of the older homes are replaced by new ones.

Improving the efficiency of lighting in new commercial buildings is another technical option that can yield substantial reductions. The Tough

scenario measures together—a combination of high-efficiency fluorescent bulbs and ballasts, improved reflectors, and better use of daylight—would lower lighting energy needs by 60 percent in these buildings (18). This achieves reductions equal to 3 percent of 1987 emissions by 2015.

Gains in commercial buildings can also be made by simply replacing existing bulbs with high-efficiency ones—without replacing fixtures—as shown under the “Operation and Maintenance” heading of table 1-1. Replacing the most heavily used incandescent bulbs in homes with compact fluorescents and using high-efficiency fluorescents in commercial buildings can lower emissions by 1.3 percent under our Tough scenario.

The instruments listed in table 1-2 and the policies described below appear to offer the most promise to achieve these reductions. While a carbon tax will certainly help, because there are so many different decisionmakers—some of whom may not be that responsive to price changes—a larger arsenal of policy instruments is needed. These include demand-side management (with the utilities as partners) as well as a series of targeted financial sanctions, incentives, and regulations.

Demand-Side Management (DSM)—DSM refers to electric utility programs designed to encourage customers to modify their patterns of energy use. Particularly promising—from a global warming perspective—are those situations where utilities allow energy conservation to compete with traditional supply technologies (e.g., powerplants) to balance energy supply and demand. DSM can be an effective approach to reduce energy consumption by improving building shells as well as the equipment inside buildings. In some cases, utilities pay for rebate programs, give out high-efficiency light bulbs, or otherwise stimulate end-use efficiency improvements, and save energy at a fraction of the cost of new power supplies.

Demand-side management can result in greater investments in energy efficiency than customers would otherwise make. Utility programs have long time horizons and can capture the potential in both the new and retrofit markets, for both equipment efficiency and building shell improvements. There is already considerable support for DSM by many

State energy offices, State legislatures, and public utility commissions.¹²

However, in order for DSM to stimulate significant investment in conservation, incentive structures must be changed so that utilities can profit from demand-side investments. Any Federal legislation concerning DSM would need to be general enough to allow States flexibility in implementation and specific enough to have a genuine impact on conservation. Congress could provide funding to evaluate various incentive structures currently being examined by States and utilities. Should Congress wish to pursue more direct action, it could require States to formally consider demand-side resources in their planning, with oversight by the Federal Energy Regulatory Commission (FERC).

The Federal and State Governments share the regulation of electric utilities, and there is a history of tension over this sharing of jurisdiction (48). Congress can play a powerful leadership role in the direction of utility planning through legislation that guides FERC (which has jurisdiction over wholesale electricity transactions). An example of such legislation is the Public Utility Regulatory Policies Act of 1978 (PURPA), which required utilities to purchase electricity from qualifying facilities at avoided cost. Recently Congress addressed some aspects of this; for example, the Omnibus Budget Reconciliation Act amended PURPA to eliminate the 80-megawatt capacity limitation for qualifying facilities fueled by wind, geothermal, solar, or waste energy.

Further, the Federal Government could mandate that environmental externalities be considered in evaluating supply-side options (as New York State has done—i.e., penalizing polluting options based on estimates of the costs of environmental damage that would accrue; ref. 33). Congress has already mandated, in the 1980 Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501), that the Northwest Power Planning Council adopt rate structures that give conservation measures a cost break over other, more traditional supply-side measures.

Technology-Specific Regulations—Congress can directly mandate efficiency improvements through appliance standards and building energy codes.

¹²For a discussion of State initiatives in least-cost planning, see ref. 40.

Appliance Standards—Appliance standards, by fiat, remove inefficient appliances from the market. The National Appliance Energy Conservation Amendments (Public Law 100-12), passed in 1988, are expected to lower residential energy use by up to 10 percent by the year 2000 (17). However, even stricter standards are possible.¹³ The law requires review of appliance standards twice during the 1990s, which provides an opportunity to obtain additional energy reductions through more stringent standards. Congress could also consider extending standards to other equipment such as commercial heating, ventilation, and air-conditioning equipment; lightbulbs; and building components such as windows.

Standards could be even more effective if used in conjunction with other incentives. Policies such as utility programs, appliance labeling, and tax schemes provide incentives to do more than standards require.

Building Energy Codes—Building energy codes serve a function analogous to that of appliance standards by preventing the least efficient buildings from being constructed. Building codes have traditionally been under the jurisdiction of States and localities. Currently, there is little support from the States or the construction industry for a mandatory national building code. In 1976, Congress enacted legislation that required the development of the Building Energy Performance Standards (BEPS), a mandatory national code based on performance standards. In 1983, the law was modified to be a mandatory code only for Federal buildings.

Greater energy savings could be achieved by:

1. mandating compliance with a uniform code or creating incentives for States to adopt the national code;
2. developing a more stringent national code; and
3. increasing funding for implementation and enforcement.

The National Affordable Housing Act of 1990 (Public Law 101-922) requires the Department of Housing and Urban Development (HUD) to develop energy efficiency standards for new public housing

and for housing subject to mortgages under the National Housing Act.¹⁴

Financial Measures—Congress can choose from among several sector-specific financial mechanisms, including building tax credits and subsidies and initial purchase taxes for appliances and other equipment.

Building Tax Credits and Subsidies—Tax credits and subsidies for using more efficient technologies can promote retrofitting of existing residential and commercial buildings. The Federal Government, for example, passed legislation that provided solar and conservation tax credits for the years 1978 through 1984. By 1983, 24 million households claimed a residential tax credit of up to \$700 each for investments in energy conservation; however, no evaluation or monitoring of energy saved by this program was ever conducted. The 1986 Tax Reform Act allowed the energy conservation tax credits for residential use to expire but extended residential solar tax credits and some commercial energy conservation credits.¹⁵

The Federal Government currently funds several subsidy programs. The Institutional Conservation Program, the Weatherization Assistance Program, and the Low Income Home Energy Assistance Program all pay for some energy conservation measures in low-income housing. The recently expired Solar Energy and Energy Conservation Bank helped finance energy conservation and cost-effective solar energy in low- and moderate-income housing and in commercial buildings owned by nonprofit organizations. Under these programs, the Federal Government provides funding to States, who in turn provide matching grants and loan subsidies. Such programs could be reinstated or expanded.

Initial Purchase Taxes and Rebates for Appliances and Other Equipment—An initial purchase tax scaled to penalize inefficient equipment could accelerate the market penetration of efficient equipment. Examples include a lump-sum tax on appliances and equipment at the time of purchase. Taxes collected on the most polluting items could be used

¹³The amendments define all energy-efficiency improvements with a payback of 3 years or less as economically justified. Any paybacks longer than 3 years must be shown to be economically justified.

¹⁴I.e., mortgages that include a loan, under the National Housing Act, for financing energy-conserving improvements or adding solar energy systems.

¹⁵The Omnibus Budget Reconciliation Act of 1990 extended the 10-percent business energy tax credit for solar and geothermal property through Dec. 31, 1991.

to provide a rebate on the least polluting items. However, although an initial purchase tax sends appropriate signals regarding consumer purchasing decisions, it would not—unlike an energy or carbon tax—change use of an appliance once it is purchased.

Consumer Information and Marketing Programs—Lack of information and uncertainty have been identified as key barriers to greater investment in energy conservation in the buildings sector. The large number of highly cost-effective investments in energy efficiency that are not chosen by consumers indicates that price alone does not stimulate optimal investment decisions. Therefore, information dissemination is a key element of several of the policy options discussed above, including the sector-specific financial measures and general energy and carbon taxes.

Home Energy Rating Systems—The Federal Government has been involved in home energy rating systems—which tell buyers how efficient their prospective homes or offices are—through its role in the mortgage market. In addition, the National Affordable Housing Act of 1990 requires HUD to develop a plan to make housing more affordable through mortgage financing incentives for energy efficiency. The Federal Government could play a further role by developing a uniform energy rating system for all residential and commercial buildings, making it easier and less expensive for lenders to include energy costs in their mortgage evaluations.

State Information Programs—The State Energy Conservation Program (SECP) provides financial assistance to the State energy offices to promote energy efficiency and conservation in commercial and residential buildings. The Energy Extension Service (EES) is a Federal/State effort to provide small-scale energy users with individually tailored technical assistance for energy conservation and increased use of renewables. The SECP and the EES were consolidated under the 1990 State Energy Conservation Programs Improvement Act (Public Law 101-440).

Energy Audits—The Federal Residential Conservation Service, created in 1978, mandated that gas and electric utilities provide their customers with onsite energy audits. The program was implemented in 1981 and recently expired. There has been little evaluation of the program, and little reliable information has been kept on its success in reducing

energy consumption. However, while it is unclear whether information from audits alone is enough to encourage conservation, it would certainly seem to be useful when combined with other measures.

Building Research, Development, and Demonstration—Major barriers to private investment in RD&D in the buildings sector include the fragmented structure of this sector and the short-term perspective of many of the decisionmakers (e.g., builders, renters). In addition, the U.S. Government currently spends a negligible amount on housing research. In contrast, in countries such as Sweden and Japan, RD&D spending has been part of a trend toward energy-efficient prefabricated housing. This spending has contributed to the energy efficiency of homes through standardization of energy-saving features and quality control in the design and manufacture of building components.

As a step, Congress has required HUD, in the National Affordable Housing Act of 1990, to develop a plan to encourage and improve energy efficiency in newly constructed, rehabilitated, and existing housing; and demonstrate various methods of improving the energy efficiency of existing housing. Such projects should encourage the development of “energy efficiency businesses” that can bridge the gap between owners, builders and occupants of buildings. Congress also required HUD to encourage the use of private energy service companies in public housing projects.

The Federal Energy Management Program (FEMP), administered by the Department of Energy, works with government agencies to implement cost-effective, energy-efficiency improvements. Congress could authorize FEMP to test and demonstrate performance, acceptance, and cost-effectiveness of new technologies in Federal buildings.

Transportation Sector

Urban passenger travel in cars and light trucks (i.e., light vehicles) in the United States requires the largest share of transport energy, consuming 15 percent of the world’s oil production. The two main opportunities for reducing transportation’s contribution to global warming are measures to increase the energy efficiency of light vehicles and measures to encourage urban passengers to drive less. Thus, under OTA’s modeling exercise, the major reductions come from higher auto and truck efficiency,

better control of traffic, and, under the Tough scenario, more use of public transit (see figure 1-7).

With respect to auto efficiency, our Base case assumes that new cars will average about 32 mpg by 2000 and about 37 mpg by 2010. Under the Moderate scenario, new car efficiency averages 35 mpg by 2000 (9) and 39 mpg by 2010 (10). Under the Tough scenario, we assume a range of new car efficiencies. For example, efficiencies of 39 mpg by 2000 and 55 mpg by 2010 might be possible even if consumers maintain their current preferences for car size and performance (10). If consumers are willing to buy smaller cars, new car fleet average efficiencies of 42 mpg by 2000 and 58 mpg by 2010 might be achievable. Given this range of assumptions, reductions amount to about 3.5 to 3.8 percent of current emissions by 2015 (see table 1-1).

Reductions of about 2.5 to 2.7 percent from light trucks and another 2.4 percent from medium- and heavy-duty trucks are achievable under our Tough scenario, as well.

Traffic speed affects fuel consumption, too. By reinstating the 55 mile-per-hour speed limit and by reducing traffic congestion in urban areas in order to speed up travel, reductions of 1.4 percent by 2015 are possible under our Tough scenario.¹⁶

Measures to move people out of their cars and into mass transit under the Tough scenario would yield reductions of about 3.5 percent by 2015. To achieve this, however, urban auto traffic would have to be reduced by 10 percent through urban light rail, busways, and improved urban design. Additionally, 5 percent of car travel between cities would have to shift to high-speed intercity rail.

The following four policy instruments will promote new car efficiency: gasoline taxes, vehicle taxes and rebates, fuel economy standards, and incentives for vehicle manufacturers. In addition, improved operation and maintenance practices will reduce energy use in existing cars. Two other measures, transportation control measures (TCMs) and controlling settlement patterns, can help reduce CO₂ by reducing vehicle miles traveled.

Gasoline Taxes—A gasoline tax would create incentives for both increased efficiency and reduced travel. Taxes would induce consumers to use less fuel while leaving them free to choose how they adjust their behavior. In concert with increasing fuel economy standards (see below), a long-term impact on the efficiency of the vehicle fleet could be achieved.

Although the effectiveness of taxes is hard to predict from studies of past responses to price changes, one might expect a 10-percent hike in gasoline prices to yield a 1- to 6-percent drop in gas consumption.¹⁷ A 50-percent increase in price might reduce consumption 5 to 20 percent over the near term, even more over the longer term. A doubling or tripling in price (approaching the costs in Europe and Japan) might yield an immediate decrease of 13 to 20 percent and a longer term response of a 35- to 40-percent reduction in gasoline consumption. About half of this longer term adjustment to high price is expected from driving less, and the other half from more efficient vehicles. For example, consumers might choose to spend money on fuel-efficient technologies or to use mass transit, carpool, or simply travel less.

A gasoline tax, however, is regressive and thus affects the poor proportionately more than the rich.¹⁸ To ameliorate this, Congress could provide rebates to low-income households. It could also phase in the tax to give consumers time to adjust their purchasing decisions and operation and management practices.

Vehicle Taxes and Rebates—Taxes on inefficient vehicles can create incentives to choose better fuel economy and forego large size and extra power. Such a program would be most effective if accompanied by rebates for highly efficient cars. In a "revenue neutral" program, the money taken in from the taxes would be redistributed through the rebates. The Federal Gas Guzzler Tax¹⁹ already applies to cars with fuel economies below certain thresholds; the Omnibus Budget Reconciliation Act of 1990 recently doubled the tax for cars getting less than 22.5 mpg.

¹⁶Cars use gasoline most efficiently in the range of 35 to 45 mph; slower travel (due to congestion) and faster travel lead to losses in efficiency.

¹⁷Two recent studies (4, 8) review the "elasticity" of gasoline use relative to price (i.e., the ratio of the percentage change in use to the percentage change in price).

¹⁸For example, in 1985, households with earnings exceeding \$35,000 spent 4 percent of income on gasoline whereas households earning \$5,000 to \$10,000 spent 11 percent.

¹⁹The Energy Tax Act of 1978 (Public Law 95-618).

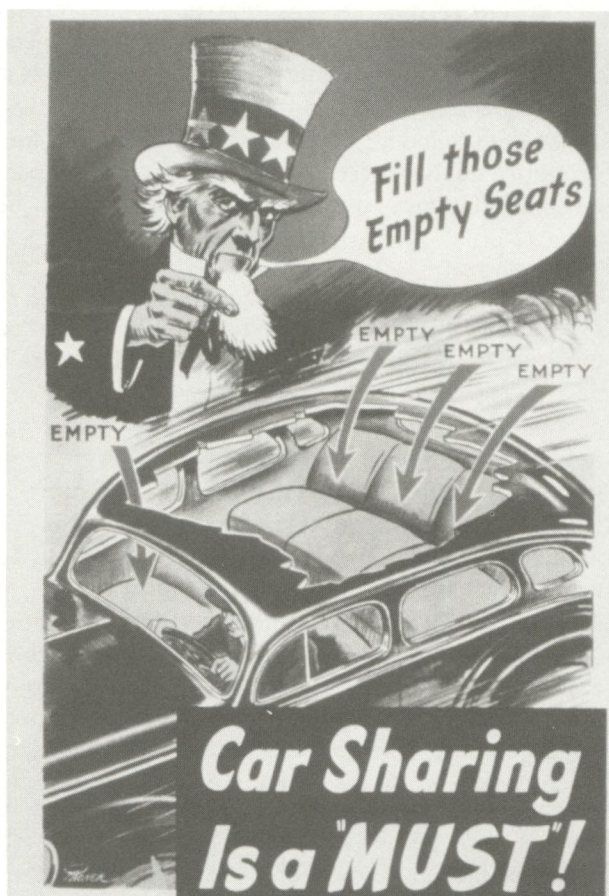


Photo credit: Bressler Editorial Cartoons, New York, Artist: Packer

A World War II poster encouraging car pooling. Urban commuters average 1.2 passengers per vehicle to and from work.

An expanded program of auto purchase taxes and rebates could complement fuel economy standards and taxes, but it could also pose serious trade difficulties as long as the high-efficiency end of the auto market is dominated by imports. If implemented suddenly, such measures would put domestic manufacturers at a disadvantage; on the other hand, measures designed to protect domestic manufacturers might conflict with General Agreement on Tariffs and Trade (GATT) rules.

Fuel Economy Standards—Standards influence the tradeoffs among cost, performance, size, and efficiency that underlie the development and introduction of new models. The current fuel economy standards for cars, in place since 1978, have helped to increase auto fuel economy (21). More stringent standards can both lower CO₂ emissions and reduce our dependence on imported oil. Redesigned stand-

ards that vary with vehicle volume can help minimize the burden on U.S. manufacturers that offer a full range of car sizes (31, 49).

Incentives for Vehicle Manufacturers—One incentive, aimed at producers instead of consumers, is the use of government-sponsored competitions to induce manufacturers to develop high-efficiency or alternate-fueled cars. A variant of the incentive scheme injects competitive elements into a high-efficiency rebate program. For example, the government could identify a few classes of vehicles most in need of fuel economy improvement and offer a competitive reward in the form of consumer rebates on a large (e.g., 200,000 units) production run of a new vehicle achieving the best fuel economy above a specified threshold.

Efficient Vehicle Operating Practices—Changes in vehicle operating practices offer small potential reductions individually but often have short startup times and do not require large, upfront capital investment. They include reimposing (and enforcing) the 55-mph speed limit; requiring efficiency inspections for trucks; and charging efficiency-promoting parking fees at Federal offices.

Transportation Control Measures (TCMs)—TCMs include a wide variety of measures to reduce the number of vehicle miles traveled (VMT) and lower congestion. They are attractive because they typically have short startup times and low capital costs, and can reduce energy use and greenhouse emissions even within existing settlement and employment patterns. In aggregate, TCMs appear to hold modest promise for reducing VMT. They include:

- ridesharing (promotion and matching services);
- employer-based transportation management (high parking charges, transit or vanpool subsidies, and expedited transactions—e.g., bus passes, van leasing, and insurance made available at work);
- High-Occupancy Vehicle (HOV) lanes (restricting lanes on freeways to cars with three or four occupants and to buses);
- parking management (parking taxes or development surcharges, restricting street parking, and mandating high parking charges at workplaces);
- Park and Ride (intercept drivers near their origins);

- mass transit improvements (bus service expansion, operational changes, and fare changes);
- travel substitution (telecommunications, work-at-home, 4-day work weeks);
- traffic flow improvements (sophisticated signals, ramp metering, intersection improvement); and
- bicycling promotion.

Under the Energy Tax Act of 1978, employer-provided vanpools between an employee's residence and place of work were excludable from the employee's income if the vehicle was capable of carrying nine people. Congress could consider reinstating this provision or a variation of it.

Under present law, employer-provided transit passes, tokens, fare cards, and employer reimbursements for travel over \$15 per month are considered taxable income. However, under current Federal tax law the value of parking provided to an employee is excludable from the gross income as a fringe benefit. Congress could consider making reimbursements for public transportation nontaxable or making parking taxable.

Controlling Settlement Patterns—Long-term reductions in emissions can be achieved by changing patterns of settlement to reduce the need for travel. This can be accomplished through higher densities, or through mixing uses so that residences, jobs, and services are roughly balanced at a local scale. When more destinations are close to home, more trips can be made by foot; when densities are higher, public transit can serve more people effectively.

In the United States, except possibly for some high-growth areas in the South and West, efforts to change the shape of settlement in major cities may meet local resistance. Nevertheless, some changes are feasible in suburban areas nationwide. Stringent suburban restrictions on development—sometimes only on commercial and industrial development, sometimes on new residential development as well—have been attempted in some regions of the United States (12).

Transportation RD&D—American automakers lag behind their Japanese, and to a lesser extent their European, counterparts in moving research results to the market (3). In the 1980s, a program to support more aggressive research and development in the American auto industry—the Cooperative Automotive Research Program—was briefly attempted by

the Department of Transportation. A revived, combined government/industry program could be successful if domestic automakers, their suppliers, and innovative research companies all are key players. The program could target important efficiency areas such as continuously variable transmissions, energy-storage systems, new engine designs for heavy trucks, improved safety for lighter vehicles, and innovations to permit increased intermodal freight.

An area of longer term research that deserves special attention is development of truly clean, economically acceptable, alternative fuels and a supporting infrastructure. Fuels with the greatest potential—electricity or hydrogen from noncarbon energy sources (e.g., solar and nuclear) and woody biomass fuels grown on a sustainable basis—are the furthest from large-scale technical viability. Research in these areas could be expanded, with parallel programs to assess and demonstrate the actual performance of a variety of fuels.

Manufacturing Sector

For manufacturing, as shown in figure 1-7, three types of technical improvements offer the greatest promise. The first area is "process changes." The top four manufacturing energy consumers (paper, chemicals, petroleum, and primary metals)—which account for more than 75 percent of energy use in this sector—improved their energy efficiency by between 2.3 and 4.3 percent per year between 1980 and 1985 (52). If this pace can be maintained, as we assume in our Tough scenario, reductions equal to about 8 percent of current emissions (by 2015) will result.

Cogenerating electricity and steam for industrial processes is a second promising option. When utilities generate electricity, about two-thirds of the energy from burning the fuel is released as heat. If electricity is generated at industrial sites where the heat can be used, the efficiency of fossil fuel use can be increased dramatically. Under our Tough scenario, we assume that 90 percent of new and replacement industrial steam boilers will cogenerate electricity. Such measures can lead to reductions equivalent to about 5.8 percent of current total U.S. emissions.

More efficient motors are a third technical improvement that can lead to substantial improvements. Moderate and Tough measures might improve motor efficiencies by 10 percent and 30

percent (1), respectively, yielding reductions of about 1.2 percent by 2015 under the Moderate scenario and 4 percent under the Tough one.

The following policy instruments could encourage these technical measures: carbon taxes, DSM, efficiency standards, marketable permits, tax incentives, informational policies, and RD&D.

Carbon Tax—A carbon tax would levy economic penalties against the highest industrial emitters of CO₂. Under such an approach, the tax would be highest on coal, low for natural gas, and zero for noncarbon sources (e.g., wind, solar, geothermal, or nuclear). For industries where the cost of energy is particularly important, carbon taxes should encourage energy efficiency, fuel switching and cogeneration.

Using several econometric models, the Congressional Budget Office estimated that a carbon tax of \$100 per ton would lower CO₂ emissions from industry by between 10 and 35 percent by the year 2000. The higher reduction estimate reflects a 70-percent reduction in coal use.

Demand-Side Management—DSM programs—joint programs between electric utilities and their customers discussed previously—can help lower electricity use in the industrial sector. The major programs are:

1. rebates to customers who install approved equipment;
2. low-interest loans to customers for conservation installations; and
3. installation of conservation equipment at utility cost (37).

Many large industrial customers of electric utilities receive special lower rates because they supply the utility with a large, dependable portion of electricity demand. Utility programs could facilitate reductions in greenhouse gas emissions if these special rates were contingent on efficient use of electricity. This differs from demand-side management in that the financial burden of improving energy efficiency is placed on the manufacturer, not the utility.

Standards—A more traditional regulatory policy is to require efficiency standards for common energy-using equipment, similar to those existing for automobiles and some appliances. Motors would be the most likely candidate for this approach.



Photo credit: American Iron and Steel Institute

About 60 percent of the fossil fuels and electricity used by industry provides process heat, steam, and cogenerated heat and steam. Energy in manufacturing is also used for feedstocks, mechanical drive, electrolysis, lighting, and space heat.

Marketable Permits—CO₂ emissions can be regulated by requiring permits for emissions; manufacturers could be issued permits based, for example, on some percentage of their 1990 emissions. Reductions might be accomplished by installing energy-efficient technologies and fuel switching; offsets could result from approved reforestation/afforestation projects. It would be up to the manufacturer to choose the most cost-effective strategy. Marketable permits would allow firms to trade their unused carbon rights to a firm that is exceeding its budget.

Manufacturing Tax Incentives—Much industrial equipment is old and energy-inefficient compared to the best available technology. In many cases, replacing old equipment improves energy efficiency by 10 to 50 percent. Financial policies, such as tax credits or accelerated tax depreciation schedules, aimed at stimulating rapid replacement of older equipment have the potential to stimulate

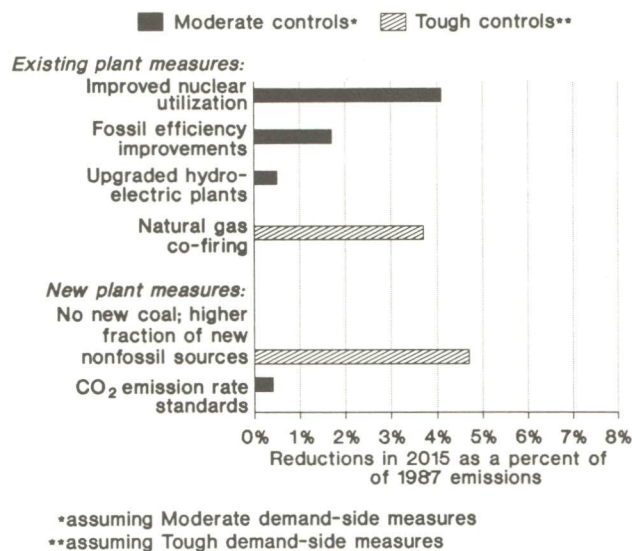
improvements in energy use. Such policies have a precedent: the Energy Tax Act of 1978 provided a 10-percent added “energy investment tax credit” for certain energy-conservation investments (as well as tax credits for some energy-supply investments). The tax credits were available until 1985 and applied to a specific list of technologies. However, rather than specify which technologies qualify, Congress could foster innovation by offering similar—or greater—tax breaks for company-chosen conservation technologies.

Informational Policies—A barrier to reducing emissions in the manufacturing sector is lack of information about how to improve energy use—especially for smaller, less energy-intensive industries. Informational policies can include performance goals, the collection of performance data, labeling of the energy performance of equipment, training, and performance audits.

Renewed support for cooperative government/industry information-sharing programs could help. For example, DOE’s Energy Analysis and Diagnostic Center program funds faculty and students at several universities to perform free energy audits for small and medium-sized manufacturers in more than 30 States. Because costs saved by manufacturers translate to increased taxable income, the program can provide additional tax revenues to the Federal Government. The biggest cost savings have come from efficiency improvements associated with cogeneration, space heating, lighting, and process equipment maintenance and replacement (in descending order of savings; ref. 25). This program could be expanded or new programs could be modeled after it.

Manufacturing R&D—Research and development sponsored by DOE’s Office of Industrial Programs in waste energy reduction and industrial process efficiency, if funded, are projected to save more than 3 to 4 percent of energy used by industry per year over the next decade. Research areas identified by Oak Ridge National Laboratory as particularly promising are: improved use of catalysts in chemical production; intelligent sensors and controls; and heat recovery and cogeneration (16). R&D in nonenergy areas, such as materials science, also holds promise for partial replacement of energy-intensive materials like steel and aluminum. Likewise, research and development to improve the quality of products made with recycled materials could help reduce energy use by increasing the

Figure 1-8—Electric Utility Supply-Side Measures



NOTE: Reductions presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

demand for recycled materials such as paper, steel, and aluminum.

Electricity Generation

About one-third of U.S. carbon emissions come from generating electricity (see figure 1-3); by 2015 under our Base case this may be as high as 45 percent. Thus measures that lower the rate of carbon emissions per kilowatt-hour (kWh) of electricity generated would translate into substantial reductions.

Figure 1-8 shows OTA’s estimate of the technical potential for emissions reductions in the electric utility sector depending on the demand for electricity and the stringency of policies. Moderate utility supply-side measures can lower emissions by about 6.6 percent (see table 1-1). The two with the greatest reduction potential are: 1) increasing the efficiency of fossil fuel-fired plants (by about 5 percent) through improved maintenance (14); and 2) operating existing nuclear powerplants 70 percent of the time (similar to Western Europe and Japan (16) and extending their useful life to 45 years.

Our Tough measures eliminate coal use wherever possible. A combination of renewable energy sources, nuclear plants with improved designs that may be available after 2005, and high-efficiency gas turbines are the only new utility plants built under the

Tough scenario. However, if all the Tough demand-side measures in the buildings and industrial sectors are implemented, growth in demand for electricity is so low that very few new plants are needed through 2015. Thus, the only way to lower emissions under this scenario is to either cofire existing coal plants (e.g., with 50 percent natural gas), or retire existing coal plants after 40 years of operation (rather than the typical 60 years) and replace them with renewable or nuclear fuels or natural gas. The former measure would reduce emissions by about 3.7 percent by 2015; the latter, by about 4.7 percent of current levels by 2015.

The following policy options could be used to encourage these technical measures: carbon taxes, marketable permits, subsidizing noncarbon sources, emissions limits and standards, and RD&D.

Carbon Taxes—A carbon tax, if set high enough, would encourage fuel switching and conservation. A carbon tax in the range of \$75 to \$150 per ton would make natural gas a more economic choice than coal at many facilities. A carbon tax would also provide added motivation to develop more noncarbon energy sources.

Marketable Permits—Utilities could be issued marketable permits for CO₂ emissions allowed from their coal-fired units, based on their generation in a historic year (e.g., 1990) multiplied by an allowed emission rate. Under this approach some utilities could curtail coal use more than necessary to meet their limits and sell permits to others exceeding their limits.

A variant on the above approach is to simply issue permits for a limited amount of coal use in existing facilities. Such an approach would be simpler to administer than emission permits, but it does not give credit to more efficient coal plants or to those plants that use lower CO₂-emitting coals.

To hold new coal plant construction between now and 2015 to a predetermined level, a limited number of coal permits (or carbon permits specific to coal plants) could be auctioned each year to the highest bidder. If such a policy were adopted in combination with marketable permits for existing coal plants, utilities could be allowed to freely trade among new and existing facilities.

Subsidize Noncarbon Sources—Any of the general financial instruments, such as a carbon tax or fossil fuel energy tax, will serve to encourage use of nonfossil sources for electricity generation. According to one estimate (40), a 2 cent-per-kWh subsidy or its equivalent²⁰ for only renewable sources of electricity might double the contribution of renewable sources of electricity by 2010—i.e., allow them to supply 40 percent of new demand under a Base case growth scenario. Under our Tough scenario, we assume nonfossil sources can provide between 30 and 45 percent of new demand (depending on the success of other demand-side measures).

CO₂ Emission Limits and Efficiency Standards—Congress could mandate reductions by setting CO₂ emission limits or efficiency standards. For example, an emission rate limit of 0.55 pounds carbon per kWh (lbs C/kWh) would require a typical Midwestern plant burning Illinois coal to burn between about 10 and 30 percent gas, depending on its efficiency. At 0.55 lbs C/kWh, the most efficient new coal burning technologies (e.g., integrated coal gasification combined cycle, or IGCC) would just qualify burning coal alone.

Two somewhat different strategies could be pursued to set CO₂ emission limits for new plants. If the intent is to force development of ultra-efficient coal technologies, then a standard in the range of 0.35 to 0.40 lbs C/kWh would be appropriate. Molten carbonate fuel cells, if successful, might be able to achieve such emission rates using bituminous coals. If the intent is to limit new fossil fuel-fired generation to the cleanest sources only—advanced combined cycle turbines burning gas—then a new source performance standard of about 0.25 lbs C/kWh would be more appropriate. To speed up replacement of old plants with new, lower emitting ones, Congress could mandate the retirement of existing fossil-fuel-fired plants earlier than their expected lifetime of 60 years.

In addition, powerplant efficiencies are not routinely monitored and industry attention to methods for improving efficiencies is only fairly recent (15). To demonstrate how better monitoring affects energy efficiency, Congress could require TVA and the Federal power agencies (e.g., Bonneville Power Authority) to undertake improvement at their own facilities. About 4 percent of the electricity gener-

²⁰A 2 cent-per-kWh subsidy is equivalent to a carbon tax of \$75 per ton of carbon for coal and about \$150 per ton of carbon for natural gas.

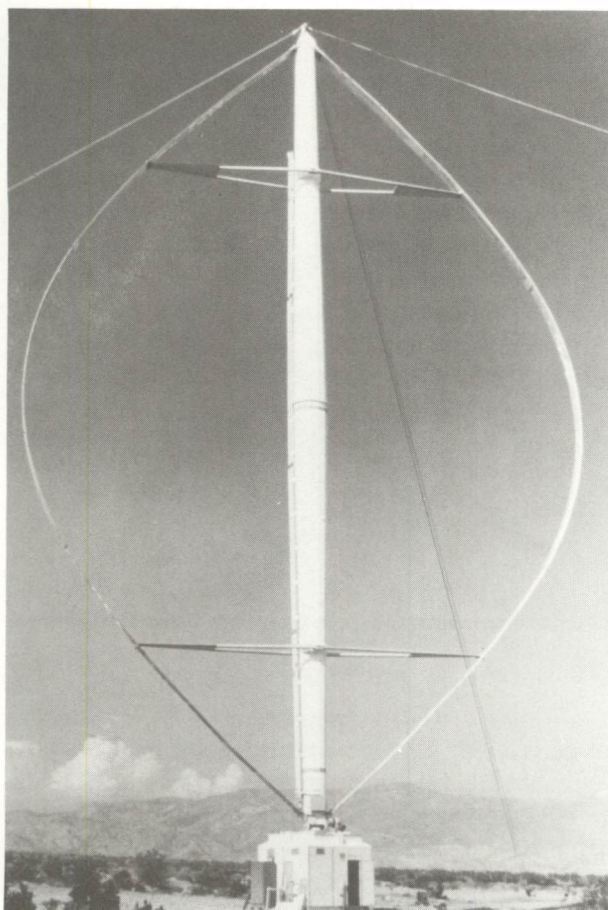


Photo credit: Southern California Edison Co.

A 500-MW wind turbine mounted on a vertical axis is insensitive to wind direction. All renewable sources of energy (wind, solar, geothermal, hydro, and biomass) currently contribute 5 to 10 percent of U.S. energy supply.

ated from fossil fuels comes from Federal power agency facilities (13).

The Federal Government, through the Federal Energy Regulatory Commission (FERC), also has indirect ability to influence private utility operations through its authority over the prices and conditions of interstate wholesale power sales. If Congress feels that the State Public Utility Commissions are not identifying and enforcing efficiency improvements, it could direct FERC to consider these issues when regulating interstate wholesale power sales.

Energy RD&D Funding—Over the last decade, Federal funding for renewable energy, conservation, and nuclear (fission) R&D fell rapidly (see figure 1-6). The 1990 combined energy technology R&D

budgets (in 1990 dollars) for these three categories were 82 percent lower than they were in 1980. To reinstate the funding levels of 10 years ago would require adding about \$2.6 billion. By doing so, the Federal Government could hasten the development and demonstration of supply technologies that would reduce greenhouse gas emissions. The most promising of these technologies include: commercial fuel cells; storage technologies for solar electricity; biomass-driven turbines; variable-speed wind turbines; and better designs for nuclear powerplants. Many experts estimate that these technologies could be commercially available within the next few decades.

The government could also play a role in reducing the perceived risk of new technologies and integrating renewable energy sources in existing energy systems by conducting demonstration projects or, perhaps, providing government-backed loans. To encourage new nuclear energy sources, a two-track process appears best: the Department of Energy could help fund full-scale demonstrations of both new “evolutionary” light water reactors and “revolutionary” design changes such as a modular high-temperature gas reactor.

For existing nuclear powerplants, the goal should be to increase the number of hours of operation, rather than to increase efficiency of fuel use. A Department of Energy demonstration program (co-ordinated with the Nuclear Regulatory Commission) might bring U.S. hours of nuclear plant operation from well below to above the average for Western Europe and Japan. Key elements of such a program would include improving preventive maintenance; installing automated controls to improve reactor operation; and speeding up time spent refueling.

Forests

Forestry-related measures with the greatest potential to offset carbon emissions include increasing the productivity of existing forests, planting trees in new areas, and growing tree crops for biomass energy; we consider these to be Tough measures, with the exception of ongoing tree planting in the Conservation Reserve Program. As shown in figure 1-9, OTA estimates that the increased carbon uptake from increasing productivity on about 60 million hectares of timberland might be equivalent to annual emissions reductions of about 3 percent of current levels by 2015. Planting new trees (i.e., afforestation) on farmland and other nonforested areas and in cities

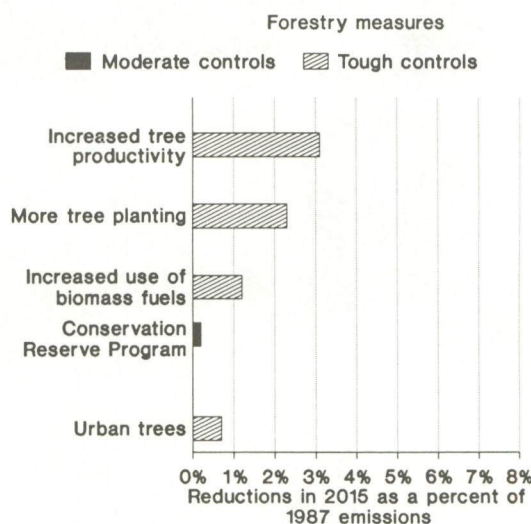
might result in carbon storage equivalent to emissions reductions of about 2 percent of current levels by 2015. Planting trees for biomass energy might result in an additional reduction of about 1 percent by 2015.

There are several caveats to this potential for offsetting emissions. Trees planted today can continue to store carbon beyond this report's 25-year timeframe. But this carbon eventually will be released to the atmosphere, either when trees die and decompose naturally, when they are harvested and burned, or when products made from wood eventually decompose. Unless the wood is used to displace fossil fuel use or is permanently stored under conditions that do not allow decomposition, carbon offsets in later years will dwindle. These estimates also assume that increasing the productivity of a forest's **commercial timber** component is equivalent to increasing the productivity of the **entire forest ecosystem**, but this assumption needs to be tested. Finally, forests—and the feasibility of using forestry practices to offset emissions—are likely to be affected by future climate changes. Therefore, forestry options in industrialized countries such as the United States cannot be considered a substitute for reducing total energy use, but rather as a way of “buying” time while developing alternative nonfossil fuel sources and improving the efficiency of energy use in general.

Congress could promote management practices that increase carbon storage or offset CO₂ emissions by augmenting existing forest management and tree planting programs of the U.S. Forest Service (USFS) and the Agricultural Stabilization and Conservation Service, and by enhancing the biomass energy research program of the Department of Energy. In addition to direct support for such programs, Congress also could consider using financial mechanisms (e.g., changing income tax policies to encourage more investments in forest management; imposing a tax on fossil fuels to make biomass fuels more competitive).

Incentives To Increase Carbon Storage on Forest Lands—Incentives to increase productivity—i.e., net carbon storage—will differ for publicly and privately owned forests. On public lands, which are located mostly in the West, management objectives

Figure 1-9—Forestry Measures



NOTE: Offsets presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

are determined by planning processes legislated by Congress.²¹ Government investments in these lands are likely to focus on reforestation and timber stand management. Congress could direct the USFS and Bureau of Land Management to, for example, increase reforestation activities and to conduct research on the ability of “new forestry” practices that proponents contend might help to both maintain higher levels of diversity and allow commodity production.

Privately owned forests are most extensive in the East and South. For **nonindustry private forests**, Congress could continue to increase assistance to States and private landowners under programs such as the Forestry Incentives Program and the Agricultural Conservation Program. These programs currently reach only about 2 percent of nonindustry private owners (32), even though these owners undertake over 40 percent of all reforestation. The Interior and Related Agencies Appropriations Act for fiscal year 1991 almost doubled funding for the USFS's State and private forestry programs, which include tree planting and management. The 1990 Food, Agriculture, Conservation, and Trade Act (Public Law 101-624), known as the 1990 Farm Bill,

²¹E.g., for National Forests in the Renewable Resources Planning Act (Public Law 93-378) and National Forest Management Act (Public Law 94-585), within the framework set forth in the Multiple-Use and Sustained-Yield Act of 1960 (Public Law 86-517).



Photo credit: James P. Blair (c) 1990 National Geographic Society

The effects of clearcutting U.S. forests can be seen on the steep slopes of the Mount Baker-Snoqualmie National Forest below the Clearwater Wilderness.

also authorized a forestry stewardship program in which the USFS would work with State and local governments, land grant universities, and the private sector to improve resource management on privately owned forest land.

For industry-owned timberland, investments might be stimulated through changes in capital gains provisions (e.g., restoring preferential tax rates or providing a partial exclusion from taxable income for timber held longer than 20 years) or allowing full annual deductions for expenses, as well as by increasing funding for Federal assistance programs. One possibility for increasing support of such programs is to use funds that would accrue if below-cost timber sales in National Forests were eliminated.

Incentives for Growing New Trees on Unforested and Urban Lands—Mechanisms to promote afforestation include the Conservation Reserve Program (CRP), the President's proposed America the Beautiful program, and financial incentives such as tax credits for carbon storage. In general, any tree-planting program needs to consider the costs of maintaining trees in a healthy state once planted; this will be even more critical as climate changes occur.

Congress could expand the CRP by increasing its tree-planting goals and its incentives for enrolling land for tree planting (e.g., higher rentals, greater share of reforestation costs, longer contracts).²² The 1990 Farm Bill expanded CRP eligibility criteria to include, for example, marginal pasture lands previously converted to wetlands or wildlife habitat,

²²Under the CRP, farmers who take lands out of production for 10 years receive annual rental payments from the Federal Government and a one-time payment for one-half the cost of establishing protective vegetation.

marginal pasture lands to be converted to trees in or near riparian areas, and croplands that contribute to water quality degradation.²³ Another option would be to encourage new shelterbelts, perhaps through tax credits or by conservation compliance requirements tied to commodity support programs.

The 1990 Farm Bill authorized startup funds for the America the Beautiful tree-planting program, as well as funds for urban and community tree planting and maintenance. The Interior and Related Agencies Appropriations Act for fiscal year 1991 did not fund the program, although, as noted above, tree planting was included in funding for the USFS's State and private forestry programs. Infrastructure for increased planting also may need to be developed, since current planting is near the historical peak, and funding for long-term maintenance also will be needed.

Congress also could consider providing tax incentives (similar to those once more widely available for energy conservation) for properly planting and maintaining urban trees, especially near homes and buildings to save energy used for cooling.

Incentives for Biomass Energy To Offset CO₂ Emissions—Growing short-rotation woody crops on nonforested land for use as an energy source shows some promise. Congress could increase funding for Department of Energy research on uncertainties regarding long-term productivity, including effects on nutrient availability, and costs. Increasing fossil fuel taxes would make biomass fuels more competitive. Even then, farmers wishing to invest in biomass crops may be limited by loss of base acreage in commodity support programs and by lack of revenues for several years. Thus, changes in support programs or provision of some subsidy may be needed to stimulate investments in biomass crops on current cropland.

Food Sector

In the other U.S. sectors, CO₂ is the primary focus of OTA's analysis, although both CFCs (e.g., in buildings and transportation) and methane (e.g., from natural gas production and distribution) also

are assessed. The food sector, though, differs in two important aspects. First, the relative importance of methane (CH₄) and N₂O emissions is greater than in other sectors. Although estimates are uncertain, the food sector may account for one-third of global CH₄ emissions and anywhere from one-tenth to one-fifth of current global N₂O emissions. Its contribution to total U.S. CH₄ emissions is roughly 9 percent (its contribution to U.S. N₂O emissions is uncertain, though).

Second, fossil fuel-related CO₂ emissions (i.e., from farm machinery, irrigation equipment, fertilizer manufacturing, food transport, processing and packaging, and cooking) and CFC emissions (primarily from refrigeration) are subsumed in the transportation, industry, and buildings analyses summarized earlier. Further, CO₂ emissions from agricultural-related deforestation in the United States are very small (although they are very important in developing countries). To place the food sector in perspective, though, we estimate that it accounts for at least 8 percent of total U.S. CO₂ emissions and about 5 percent of U.S. CFC-11 and CFC-12 emissions (worldwide, it may account for one-fifth of global CO₂ emissions and up to 15 percent of global CFC-11 and CFC-12 emissions).²⁴

In the past, congressional concern about agriculture largely has focused on farm production, promotion, and income. With the passage of the 1985 Food Security Act, Congress began dealing with some of the environmental impacts of U.S. agriculture. Although the 1990 Farm Bill expanded these efforts, including extending the CRP until 1995, additional steps can still be taken, as discussed below for methane and nitrous oxide emissions.

Some of the opportunities discussed earlier for the buildings, industry, and transportation sectors also can affect food sector activities (e.g., more efficient cooking, processing and packaging, etc.). In addition, fossil fuel-related CO₂ emissions from the U.S. food system could be reduced by making fertilizer manufacture, farm machinery, and irrigation more energy efficient.

²³This will enhance the chances of achieving the CRP's goal of reducing soil erosion problems; some of these lands could be devoted to tree planting.

²⁴About 70 percent of the U.S. food sector's CO₂ emissions (i.e., about 5 percent of total U.S. CO₂ emissions) comes from fossil fuel combustion for food refrigeration, residential cooking, and food processing and packaging; the remainder comes from farm machinery, fertilizer manufacturing, and onfarm electricity use. These CO₂ emissions do not represent a complete accounting of emissions from the U.S. food sector; for example, CO₂ emissions associated with food transport are not included.

Reducing Methane Emissions—U.S. methane emissions from the food sector are primarily from ruminant animals (e.g., cattle, sheep). Congress could direct the U.S. Department of Agriculture (USDA) to determine the potential for techniques such as improved nutrient management, feed additives, and manure management to reduce methane emissions. To limit future growth in, or even reduce, livestock populations in the United States, Congress could consider reducing or removing price supports for feed grains, which might make beef and dairy products more expensive (although it is unclear if the costs would rise or fall over the long term). Such a policy could cause large near-term economic disruptions for some farmers and portions of the food industry, however.

Reducing N_2O Emissions—To reduce nitrous oxide emissions, Congress could modify commodity program policies, which now encourage monocropping and heavy fertilizer use, to give farmers more control over the types of crops they plant without losing program crop base acreage and support payments.²⁵ Congress could provide cropping flexibility only to those farmers who adopt environmentally sound cropping patterns. Congress also could make implementation of best management practices (BMPs) a prerequisite for receiving Federal price and income supports. BMPs, designed by the Soil Conservation Service (SCS) to reduce soil degradation and water contamination from agricultural activities, include more efficient fertilizer use, water impoundments, permanent vegetative cover, and manure storage.²⁶ At present, however, the SCS does not have statutory authority to promulgate enforceable regulations. Such a cross-compliance policy also would not apply to the one-third of U.S. croplands that are not enrolled in Federal farm support programs. In addition, enrolling more farm land in the CRP would help reduce N_2O emissions from fertilizer use (as well as CO_2 emissions from onfarm fossil fuel use and offsite fertilizer manufacturing).

Food RD&D—The development of an accurate emissions database for the food sector is perhaps the most critical research priority. Increased research is needed to quantify CO_2 emissions from agricultural

land-clearing activities, CH_4 emissions from ruminant animals (and from rice cultivation, particularly in the developing world), and N_2O emissions from nitrogenous fertilizers. The emissions reduction potential of different alternative practices must also be investigated; for example, support is needed for research on methane-reducing techniques, especially for livestock in confined and range-management systems. Congress also could increase funding for RD&D efforts to develop new alternative practices, especially those that simultaneously increase crop yields and reduce greenhouse gas emissions per unit of food output.

U.S. INFLUENCE ON THE REST OF THE WORLD

There are many reasons why the U.S. Congress should seek to promote the reduction of greenhouse gas emissions abroad. **First, climate change is a global problem.** Solutions must come from all emitters, as reductions made by one country will only make a small dent in total greenhouse gas emissions.

Second, emissions of greenhouse gases will rise in the developing countries. Because the developing countries have higher growth rates for energy use, population, and Gross National Product (GNP) than do industrialized countries, and because their current energy use per person is so low, their emissions of greenhouse gases will continue to rise significantly. Stabilizing or even reducing greenhouse gas emissions from developing countries will be next to impossible to achieve (at least until nonfossil energy sources are widely available), given their need to increase energy consumption for supplying basic services. However, the United States could influence emissions growth rates in developing countries and also assist these countries to achieve economic progress by helping them to increase energy production based on nonfossil fuels (e.g., solar or nuclear) and to make both their energy production and consumption more efficient.

Third, energy-related improvements may be cheaper and relatively greater—at least in the short term—in developing countries, Eastern

²⁵The 1990 Farm Bill now allows farmers to plant a limited amount of selected crops on land designated for other commodity program crops without losing program benefits.

²⁶This idea also could be extended to other energy-intensive inputs such as pesticides and irrigation water. For example, the SCS could establish guidelines on how, and in what quantities, various inputs should be applied to crops in specific regions of the country.

Europe, and the U.S.S.R. than in the United States. For example, because energy use in all the sectors of the U.S.S.R. and Eastern Europe is relatively inefficient, significant efficiency gains may be achieved at modest expense. In developing countries, much of the energy infrastructure is yet to be built; these countries can take advantage, for example, of new technologies that may be cost-effective for new construction but expensive for retrofits.

Fourth, tropical deforestation contributes between 7 and about 30 percent of worldwide CO₂ emissions; these forests are being lost at an estimated rate of over 17 million hectares per year—an area exceeding that of Virginia and West Virginia combined. In addition, much more than CO₂ emissions is at stake. Tropical forests harbor at least half of the world's species, are the source of many products used by people living in the forests and elsewhere in the world (e.g., medicines, nuts, fibers, fruits), and serve many critical functions such as watershed protection.

Developing Countries

The OECD countries (which include the United States), U.S.S.R., and Eastern Europe currently contribute about one-half to two-thirds of all greenhouse gas emissions, mostly from combustion of fossil fuels to power their economies (see figure 1-1; note the caveat on the figure regarding how the wide range of estimates of CO₂ emissions from deforestation affects estimates of the relative contribution from each region). In contrast, developing countries contribute about one-third to one-half of emissions, mostly from land use changes and practices (e.g., deforestation of tropical forests, cultivation of rice, and raising of livestock).

Most current forest-related greenhouse emissions come from tropical forests, which are located almost exclusively in developing countries and which are being felled, burned, and degraded on an unprecedented scale.²⁷ In contrast, loss of temperate-zone forests, located mostly in developed countries, currently contributes little to CO₂ emissions, although many of these forests were cleared in the past.

The major causes of tropical deforestation and degradation are the conversion of forests to temporary agriculture (e.g., "shifting" cultivation) and permanent agriculture (including cattle ranching), and poor timber harvesting practices. However, these are driven by underlying social, economic, and political factors—poverty and lack of land tenure for most people, national development policies, and foreign debts—that are exacerbated by rapid population growth (60). These factors encourage rapid exploitation of natural resources, for example to expand development and obtain foreign currency for servicing debts.

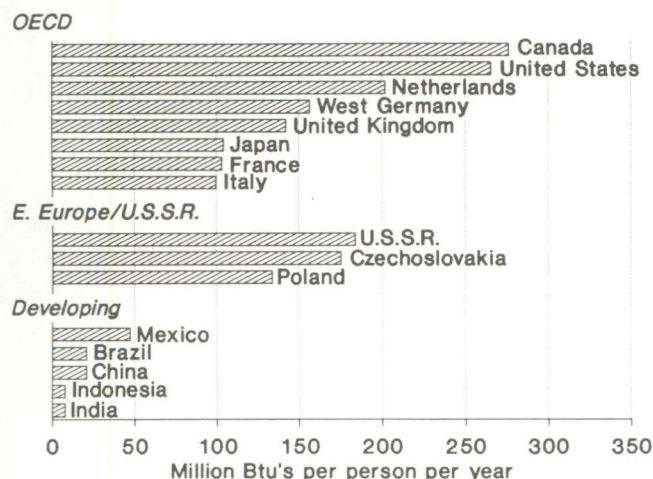
Emissions from fossil fuel use in developing countries are relatively less important now but will increase significantly in the future. Decisions that these countries make within the next 5 to 10 years about how to pursue economic growth and expand energy services and infrastructure (e.g., industrial bases, electric generation) will influence their share of emissions for decades to come. The ongoing OTA assessment, "Fueling Development: Energy and Technology in Developing Countries," will continue to examine this issue. A background report (51) discusses linkages between energy use, economic development, and environmental quality.

Figure 1-10 shows the great disparity in per-capita energy use in different parts of the world. Although a person in a developing country uses about one-fifteenth the amount of energy as does the average U.S. citizen,²⁸ even modest gains in per-capita and total economic growth in these countries translates into emissions that will exceed those from the developed world within a few decades. And such growth is likely to be more than moderate. Developing countries have been increasing their total energy use by approximately 6 percent per year, in contrast to 1 percent in OECD countries, and they increased their electrical power consumption by an average of 8 percent per year between 1971 and 1987; most of the added electrical capacity was provided by conventional powerplants (which are high CO₂ emitters) and was used for manufacturing and in buildings (43). Further increases will be needed since many countries are continuing to fully electrify cities and beginning or continuing rural electrifica-

²⁷"Deforestation" means converting forest land to other vegetation or uses (e.g., pasture, cropland, dams). "Degradation" involves practices that leave trees as the predominant vegetation but degrade overall forest quality (e.g., soil erosion; damages to trees and streams from selective logging).

²⁸The average American uses about 260 million Btu's. The average for the entire developing world (defined by the World Bank as "lower and middle income" countries) is about 20 million Btu's. The average for the selected developing countries shown in figure 1-10 is 25 million Btu's.

Figure 1-10—Per Capita Energy Consumption



SOURCES: U.S. Congress, Office of Technology Assessment, *Energy in Developing Countries*, OTA-E-486 (Washington, DC: U.S. Government Printing Office, January 1991).

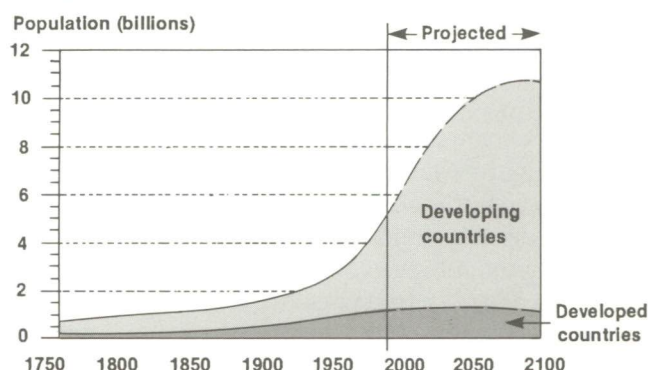
tion programs, and since refrigeration and air-conditioning are becoming more widely available. Moreover, rapid population growth, in combination with economic growth, will continue to fuel increased demands for energy and land resources long beyond the time frame of this study; the world population now grows by over 10,000 people per hour (figure 1-11), with virtually all of that growth occurring in developing countries.

U.S.S.R. and Eastern Europe

The economies of the U.S.S.R. and of Eastern European countries have been centrally planned for decades but now are changing, rapidly in some cases.²⁹ These countries account for about one-fifth of current global greenhouse gas emissions, mostly from the combustion of fossil fuels to provide energy. In 1988, the U.S.S.R. accounted for 18 percent of global primary energy consumption, Eastern Europe for 6 percent. The energy infrastructure in place in these countries is generally old and inefficient.

Efforts to promote energy conservation and efficiency in Eastern Europe and the U.S.S.R., and thereby reduce future growth in carbon emissions, face major obstacles. First, energy is highly subsi-

Figure 1-11—World Population Growth, 1750-2100



SOURCE: Population Reference Bureau, *1990 World Population Data Sheet* (Washington, DC: 1990).

dized, so consumers (particularly industries) bear only a small portion of its real costs.³⁰ Second, the central economic planning systems set rigid quotas for production (i.e., gross output) of goods and services. Enterprises must consume virtually all of the supplies allocated to them by central planners, even when not all are needed, in order to receive the same amount next year. Third, the production quotas require investments in heavy industries (e.g., steel, aluminum, chemicals) at the expense of services and consumer goods. Finally, implementation of plans for alternative energy sources is hindered by a fragmentation of responsibilities among multiple government agencies.

Thus, even when opportunities exist, there are strong disincentives to save energy and raw materials or to invest in energy efficiency. These obstacles have led to high industrial demand for energy, energy-inefficient production of goods and services, less availability of electricity for nonindustrial consumers, low standards of living, and severe environmental problems in many areas.

U.S. Policy Options To Help Limit Greenhouse Gas Emissions Abroad

Earlier sections in this summary set forth specific policy options that the United States could pursue to reduce or offset its own greenhouse gas emissions. By taking such actions to reduce its own emissions, the United States can provide leadership through

²⁹Eastern Europe as defined here includes Bulgaria, Czechoslovakia, East Germany (prior to unification with West Germany), Hungary, Poland, and Romania.

³⁰In Poland, for example, subsidies accounted for 49 percent of the delivered price of coal and 83 percent of the delivered price of natural gas in 1987 (ref. 41).

example. In the broader context, the United States also can work towards the adoption of international conventions and protocols regarding climate change, similar to those developed for phasing out CFCs and halons.

The United States also can attempt to help developing countries, Eastern Europe, and the U.S.S.R. to minimize their greenhouse gas emissions, without hindering the prospects for needed economic development. Indeed, strategies to lower greenhouse emissions can simultaneously help these nations become more economically efficient. Numerous existing programs and organizations in the United States and on the international scene directly influence development and indirectly can affect greenhouse gas emissions (see box 1-C). The United States, for example, provides direct bilateral assistance through the U.S. Agency for International Development (A.I.D.). Numerous other U.S. agencies—such as the State Department, the Commerce Department, the U.S. Trade Representative, the Treasury Department, the Agriculture Department, and the Environmental Protection Agency—support technology transfer and development assistance in certain areas. Through these U.S. and international organizations, the United States currently contributes about \$9 billion annually in foreign aid assistance (including bilateral aid, food aid, security-related economic support funds, and multilateral aid) to developing countries.³¹

The United States can continue to work through its own bilateral assistance programs and international organizations, as well as through NGOs, to increase the development and transfer of technologies and policies related to energy, family planning, and land use and management practices that provide sustainable alternatives to deforestation and dependence on fossil fuels. General congressional issues regarding developing countries, the U.S.S.R., and Eastern Europe fall into five categories:

- technology transfer and trade;
- building local institutional capacities;
- redirecting energy policies;
- redirecting natural resource policies; and
- redirecting family planning assistance policies.

Technology Transfer and Trade With Other Countries

The opportunity seems ripe for U.S. businesses to increase exports of energy-efficient and renewable energy technologies (as well as CFC-free technologies) to developing countries, since much of the energy infrastructure needed to fulfill development aspirations has yet to be built. For example, a market of \$370 to \$900 billion for electric power equipment is expected over the next 20 years (43). In addition, the U.S.S.R. and Eastern Europe have antiquated infrastructures in place; in these countries, the United States could provide modern equipment, as well as engineering and management services.

The U.S. Government promotes private sector technology transfer to non-OECD countries through government departmental programs (e.g., the Committee on Renewable Energy Commerce and Trade, or CORECT, led by the Department of Energy) and through independent government agencies and corporations (e.g., Eximbank, Overseas Private Investment Corp.). Some programs focus directly on energy technologies, while others are more general in nature.

Options—Congress could attempt to facilitate U.S. trade in renewable and efficient energy technologies in several ways. First, it could expand the financial resources of agencies that fund feasibility studies and project preparation (e.g., A.I.D., U.S. Trade and Development Program) or that provide financing for exports (e.g., Eximbank, Overseas Private Investment Corp.), as well as direct them to focus some resources on specific technology areas. For example, the fiscal year 1990 Foreign Operations Appropriations Act (Public Law 101-167) directs Eximbank to set aside 5 percent of its energy industry export funds for renewable energy projects. The Act also directed A.I.D. to focus on energy efficiency, renewable energy resources, and least-cost energy planning in the development of national energy plans, but additional funds were not appropriated. The Overseas Private Investment Corp. is planning a \$100 million Environmental Investment Fund.

³¹Compared to other countries, U.S. foreign aid and assistance is a relatively smaller percentage of its GNP. The U.S. portion was 0.19 percent in 1987 and 0.21 percent in 1988. In 1987, the larger Western European countries provided an average of 0.42 percent and Japan provided 0.31 percent; Norway topped the list at 1.1 percent.

Box 1-C—Agencies and Organizations That Can Influence Greenhouse Emissions Abroad

This box briefly describes major U.S. and international “players” looking at climate change. While no organization seems to place a premium on discouraging climate-modifying emissions *for that reason alone*, most are exploring the ways in which their policies and programs may affect climate change. In addition to those listed below, there are also many regional organizations, industry-sponsored consortia, non-governmental organizations, and philanthropic foundations that influence energy and environment policy internationally.

U.S. Government Agencies

The *Agency for International Development* is the lead agency for administering foreign economic assistance, through training, education and research, policy advice, technical assistance, and technology transfer. It is the second largest bilateral aid donor in the world (following Japan), spending over \$2 billion in 1989 on nonmilitary Overseas Development Assistance. Of that sum, about 1 percent (between \$100 to \$200 million) is spent on energy projects. A.I.D. is presently undertaking an inventory of its activities and their related effect on climate change.

The *Department of Agriculture* promotes U.S. agricultural products and coordinates agricultural trade policy with other U.S. agencies. The Forest Service administers timber sales and other activities in national forests and is involved in international forestry issues. The Agricultural Stabilization and Conservation Service administers programs that provide cost-sharing for tree planting and forest management.

The *Department of Commerce* supports U.S. manufacturers and businesses in pursuing overseas export opportunities, collects and disseminates commercial information, and supports other U.S. overseas programs, including the Eximbank and the Overseas Private Investment Corp.

The *Department of Energy* is exploring, as a part of the forthcoming National Energy Strategy, how the U.S. energy program contributes to climate change problems and what technologies may be best suited to mitigate the problems. Among other programs, the department leads the multi-agency Committee on Renewable Energy Commerce and Trade, which promotes trade of U.S. renewable energy technologies.

The *Department of State* has responsibility for overall conduct of U.S. foreign policy. It is the lead agency in negotiating any international agreements and heads U.S. participation in the IPCC process.

The *Department of Treasury* has primary responsibility for U.S. financial policies affecting other countries and for international financial institutions. The department’s Office of Multilateral Development Banks directs the U.S. Executive Directors that sit on the boards of the multilateral development banks (e.g., the World Bank); through the directors, the United States has been active in scrutinizing the banks’ environmental policies. The department examines approximately 400 bank projects per year that might have adverse environmental effects.

The *Environmental Protection Agency* is examining climate change issues (including energy use, deforestation, sea-level rise, CFCs, and methane) in developed and developing countries; it provided technical support for U.S. involvement in the IPCC.

The *U.S. Trade Representative* is charged with formulating overall trade policy and with bilateral and multilateral trade negotiations.

Independent U.S. Agencies/Corporations

The *Export-Import Bank* (Eximbank) is an independent government agency that facilitates exports of U.S. goods and services, particularly in developing countries. Its main programs include direct loans to foreign borrowers, export credit guarantees and insurance, and discount loans. Since it is not a development assistance agency, it must have a reasonable assurance of repayment.

The *Overseas Private Investment Corp.* (OPIC) is a public/private corporation created by Congress that directly finances projects sponsored by U.S. private investors in developing countries and provides insurance against political risks for U.S. private investments in those countries. In 1987, OPIC accounted for over \$8 billion in insurance and \$230 million in directly financed projects.

The *U.S. Trade and Development Program*, housed in the U.S. International Development Cooperation Agency, funds feasibility and planning studies for projects involving export markets for U.S. goods and services; its focus is primarily on large public sector projects.

Continued on next page

Box 1-C—Agencies and Organizations That Can Influence Greenhouse Emissions Abroad—Continued

Multilateral Development Banks (MDBs)

The *World Bank*, the largest multilateral development bank, spent approximately \$15 billion in 1989, including \$3.3 billion in the energy sector. Bank funding for free-standing environmental projects from 1990 through 1992 is expected to be about \$1.3 billion. The Bank recently issued an operational directive outlining procedures for assessing the environmental consequences of proposed projects; it is too early to ascertain its effects. In 1990, the United States lost its position as the largest international aid donor to Japan. This change will reduce the U.S. voting share in the Bank.¹

The three regional MDBs—the *Asian Development Bank*, *African Development Bank*, and *Inter-American Development Bank*—are also major sources of assistance and have a larger role than the World Bank in many countries, for example in Central America. The latter two banks have provided about \$1 billion for energy sector projects since 1988. The Inter-American Development Bank, like the World Bank, has established procedures for evaluating environmental impacts.

United Nations Agencies

The *UN Development Program* (UNDP) provides funding and advisory services to developing countries dealing with trade in development technology. It spent approximately \$122 million in 1988 for natural resource, energy, and environment projects.

The *UN Food and Agriculture Organization* (FAO) is active in rural and agricultural research and development, fuelwood and charcoal projects, and forestry issues (including coordinating the Tropical Forestry Action Plan).

The *UN Population Fund* (UNFPA) provides technical and monetary assistance to developing countries on population issues. It provided about \$169 million in 1988 for programs in 141 developing countries.

The *UN Environment Program* (UNEP) coordinates environmental activities within the United Nations and led the development of the Montreal Protocol to Protect the Ozone Layer. Along with the World Meteorological Organization, UNEP coordinated the Intergovernmental Panel on Climate Change (IPCC), and is one of the managers of the World Climate Program.

The *UN Industrial Development Organization* (UNIDO) promotes industrialization in developing countries and provides assistance to improve industrial use of energy.

The *World Meteorological Organization* (WMO) monitors climate trends, provides a framework for research on global climate models, and facilitates the exchange of meteorological information between countries. Along with UNEP, it plays an important role in many activities involving climate change issues (see UNEP above).

International Science and Natural Resource Organizations

The *International Council of Scientific Unions* coordinates scientific research projects worldwide and works with non-governmental organizations and intergovernmental agencies. It runs the International Geosphere-Biosphere Program and is a joint manager of the World Climate Program with UNEP and WMO.

The *Intergovernmental Panel on Climate Change* (IPCC), set up in 1988 under the auspices of UNEP and WMO, has been the primary international forum for addressing climate change. Its three working groups were charged with: 1) assessing scientific evidence on climate change; 2) assessing likely impacts resulting from such change; and 3) considering possible response strategies for limiting or adapting to climate change. The groups were chaired by the United Kingdom, U.S.S.R., and United States, respectively. The IPCC's final report was presented to the UN General Assembly in the fall of 1990.

Other organizations focus on agriculture and forestry. The *International Fund for Agricultural Development*, funded by OPEC and OECD members, makes financial resources available on concessional terms for agricultural development in developing countries. The *Consultative Group on International Agricultural Research* is a network of organizations that conducts agricultural research in developing countries. The *International Tropical Timber Organization* provides a framework for coordination between tropical timber producing and consuming countries, and the *Tropical Forestry Action Plan* attempts to enhance donor cooperation and funding in sustainable forestry management.

¹In 1984, the United States had 19.5 percent of the voting power in the World Bank. This was larger than the combined voting power of the next three highest donors.

On December 26, 1990, the United States announced that it will double the number of joint trade-promotion programs in 1991; top priority will be given to helping the U.S.S.R. increase its oil and gas exploration and production capabilities—a means of obtaining needed hard currency. In December 1990, the President also approved credit guarantees for Soviet purchases of up to \$1 billion in American commodities, making the U.S.S.R. eligible for some Eximbank credits and guarantees. However, the continuing upheaval in the U.S.S.R. suggests that the Soviets may be unable to take full advantage of these programs for some time. In addition, the June 1990 trade agreement signed by President Bush will not be submitted to Congress for approval until Soviet emigration laws are revised, so “Most Favored Nation” status cannot yet be conferred on the U.S.S.R.

Second, Congress could continue the process of streamlining restrictions on technology exports to Eastern Europe and the U.S.S.R. This could be done as part of the reauthorization of the Export Administration Act and/or by providing new directions on U.S. participation in the Coordinating Committee on Multilateral Export Controls (COCOM), a nontreaty agreement among 17 Western countries established to harmonize export control policies.

Third, Congress could provide further direction regarding “tied-aid” financing (i.e., linking foreign aid to financing of foreign purchases of U.S. products); such financing runs counter to free market policies but is used by other OECD countries. Congress already appropriated some resources for tied-aid financing to Eximbank, which decided to join with A.I.D. in creating a \$500 million tied-aid pool to leverage financing for exports of U.S. products.

Congress also could consider supporting—with the cooperation of the host countries and perhaps in conjunction with other donor countries—technology research and/or assistance centers in Eastern Europe and developing countries. EPA already is coordinating the establishment of the Budapest Center in Hungary, and A.I.D. has proposed that a Global Energy Efficiency Initiative be developed to promote pricing reform, end-use energy efficiency, cogeneration, and private-sector activities.



Photo credit: W. Westermeyer

St. Basil's Cathedral, located on the edge of Red Square in Moscow, U.S.S.R. The Soviet infrastructure is both massive and inefficient; investments are needed both in new, more efficient facilities and in retrofitting existing facilities for better energy use.

Building Local Institutional Capacities

Many developing country and Eastern European governmental agencies and NGOs lack the resources and experience needed to plan and implement projects, meet requirements of international donors, and assess the impact of policies and budgets on resources (29, 61). Building the institutional capacities of these governmental agencies and NGOs is critical to the success of energy and natural resource policies and programs. Bilateral agencies such as A.I.D. and multilateral assistance agencies such as the World Bank, United Nations Development Program (UNDP), and United Nations Environment Program (UNEP) already provide some assistance to help build these institutional capabilities.³²

³²The 1989 International Development and Finance Act (Public Law 101-240) requires the U.S. Executive Directors to the multilateral development banks to promote increased assistance and support for non-U.S. NGOs.

Options—Congress could direct A.I.D. to evaluate the effectiveness of its activities in this area. If found lacking, Congress could direct A.I.D. to increase its emphasis on this component. This would likely require increased funding for education and training; environmental information gathering and analysis; conservation planning and policy analysis; and coordination of regional authorities and community-based organizations.

Redirecting Natural Resources Policy

Most developing country economies are based on natural resources (29, 61), many of which have been exploited rapidly during the past few decades. However, short-term revenue gains have come at the expense of the underlying resource base and the long-term economic outlook for some countries. During the 1980s, for example, some countries that once were net exporters of tropical hardwood products found that their forests could no longer maintain a positive export flow. Resource depletion in one area also can have unintended consequences elsewhere—e.g., upland deforestation has increased silting of reservoirs and flooding in many downstream areas.

Many national and multilateral development policies foster resource exploitation, including subsidies for cattle ranching and short-term, low-rent licenses for timber harvesting. Fortunately, direct bilateral and multilateral assistance is beginning to be restructured to promote more environmentally sensitive economic development, although much more needs to be done. A.I.D., the World Bank, the Inter-American Development Bank, and UNDP, among others, are all developing or have recently adopted environmental assessment guidelines.

In addition, the food sector in developing countries is a major direct source of greenhouse gas emissions, particularly methane from cultivating rice and raising livestock. Most people in developing countries also rely on biomass fuels to meet their cooking and heating needs; in some cases, this has led to localized deforestation (from cutting fuelwood) or loss of soil nutrients (when dung and agricultural residues are used as fuels).

Options—Congress could influence what happens in tropical forests through several means:

1. encourage continued change in multilateral development bank (MDB) policies. For example, Congress should continue to review MDB

progress in implementing environmental impact assessment procedures, and in making loans contingent on host country development policies (e.g., eliminating subsidies that encourage inappropriate cattle ranching and poor logging);

2. increase funding for A.I.D. projects on agroforestry, sustainable agriculture, natural forest management, and nontimber forest products;
3. direct A.I.D. and the State Department to help make the Tropical Forestry Action Plan and the International Tropical Timber Organization, both of which have been severely criticized lately, more effective vehicles for promoting forest conservation and improved commercial forest management;
4. support development of a global forestry conservation protocol;
5. address family planning, land reform, and debt reduction issues; and
6. provide directions for U.S. participation as a donor in the new Global Environmental Facility, established in November 1990 (and coordinated by UNEP, UNDP, and the World Bank) to provide funding for projects on greenhouse gases (e.g., non-CO₂-emitting energy sources, energy efficiency, reforestation, CFC substitutes), biological diversity, and marine pollution.

The United States also can have some influence on emissions directly emanating from the food sectors of developing countries. Some of the policies described above for tropical forests, for example, would specifically involve agricultural projects. U.S. bilateral aid programs could attempt to introduce more efficient (in terms of greenhouse gas emissions) agricultural practices; this must, however, be carefully tailored to fit existing social traditions and economic conditions. At the same time, Congress could help fund, through U.S. bilateral aid programs and through multilateral lending organizations, various research organizations (e.g., the Consultative Group on International Agricultural Research centers) so that they could expand existing programs in developing countries to include methane reductions from livestock.

Redirecting Energy Policies

A.I.D., United Nations agencies, and the World Bank's Energy Sector Management Assistance Program provided over \$200 million in fiscal year 1988

for energy-related grants and assistance; in addition, over \$6 billion was provided for energy-related loans. Including technical assistance from other countries and technical support derived from portions of the loans, total technical assistance for energy may be on the order of \$500 million per year—less than 1 percent of total annual energy expenditures by developing countries (28).

Until recently, much of this assistance, particularly that from bank loans, focused on conventional energy supply projects such as large hydroelectric dams and coal plants. In 1989, for example, World Bank lending for solar, geothermal, and wood-based energy projects amounted to less than 1 percent of its energy sector funding. Similarly, energy efficiency has not been a significant focus (57).

Options—Congress could redirect U.S. (and attempt to redirect multilateral) energy policies away from large-scale energy projects, such as oil- and coal-fired powerplants, and toward energy efficiency, renewable technologies, and least-cost planning. Congress could ensure that A.I.D. and the Department of Treasury have sufficient resources allocated to comply with the provisions of the fiscal year 1990 Foreign Operations Appropriations Act (Public Law 101-167), which is a step in this direction.³³

Congress also could consider expanding A.I.D.'s Office of Energy program, which provides assistance to developing countries in formulating strategies for price reform. Similarly, it could encourage A.I.D. and the MDBs to work with the Eastern European and Soviet governments to initiate reforms in pricing policies.

To overcome agency reluctance to fund small projects, Congress could promote “bundling”—combining several small energy projects into one large project that supplies a substantial amount of energy and involves financial scales customarily handled by large development banks (e.g., \$5 million or more). Public Law 101-167 instructs the Secretary of Treasury to work with borrowing countries to develop loans for bundled projects on end-use energy efficiency and renewable energy.



Photo credit: African Development Foundation

The juxtaposition of old and new technology: Guide leads oxen around solar cells at water pump, part of the Basaisa Project, Egypt.

Congress also could promote greater funding by smaller development organizations.³⁴ For example, the Inter-American Foundation (IAF) and the African Development Foundation (ADF) work closely with the larger Inter-American and African Development Banks to fund or implement community-scale, grassroots development programs. These smaller foundations generally have a greater ability to examine smaller scale, modular programs than do their parent organizations, but to date they have rarely been involved in energy projects.

Population Policy Issues

The U.S. Government supported the right of couples worldwide to control the number and spacing of their children beginning in the mid-1960s; under the Foreign Assistance Act as amended in 1965, family planning is considered an important contributor to economic development and improved health and nutrition (11, 46). Most nations now firmly support family planning assistance.

However, at the world population conference held in Mexico City in 1984, the United States reversed its historic position by declaring that population growth was a “neutral” factor and that economic

³³Public Law 101-167 directed A.I.D. to identify key middle- and low-income countries in which energy and forestry policies could significantly reduce greenhouse gas emissions. Four countries—China, Brazil, Indonesia, India—appear to emit as much greenhouse gases as the other developing countries combined. Other countries considered strong candidates for attention include Poland, Egypt, Mexico, Thailand, Colombia, the Philippines, Bangladesh, Nigeria, and Zaire. A.I.D. currently does not provide direct assistance to China, Poland, or Mexico.

³⁴Other mechanisms to facilitate private-sector trade in energy-efficient and renewable energy technologies were discussed above (see “Technology Transfer and Trade With Other Countries” above).

development could compensate for any population level. Associated with this change were new restrictions on A.I.D. Thus, two important international population assistance programs lost U.S. funds—the International Planned Parenthood Federation at the end of 1984, and the United Nations Population Fund (UNFPA) in early 1986. Moreover, U.S. funding earmarked specifically for A.I.D.'s main population account has declined in recent years, from \$290 million in fiscal year 1985 to an estimated \$218 million in fiscal year 1990 (44).³⁵

Some people argue that family planning assistance should be reduced or eliminated as a part of international aid (11). However, the UNFPA (38) concluded that more assistance is needed if the world's population is to stabilize—sometime early in the 22d century—at a level of 10 or 11 billion people (this is the UN's "mid-range" projection). In particular, more assistance is needed to eliminate the large "unmet need" for family planning services; the UNFPA estimates that the additional direct cost of providing contraceptive services would likely be less than \$1 billion per year, but that several billion dollars per year also are needed for a range of backup activities (e.g., education and communication, women's programs, research and evaluation).

Any global warming policies thus must include decisions on the U.S. role in international family planning. As indicated above, this issue has been and still is highly contentious. Nevertheless, Congress could reconsider the appropriate level of funding, how funds should be distributed, and under what restrictions or sanctions they should be distributed.

CONCLUDING REMARKS

Currently, the United States and other industrialized countries (including the U.S.S.R. and Eastern Europe) contribute up to two-thirds of all greenhouse gas emissions, mostly from fossil fuels used to power these highly energy-consumptive societies. There are opportunities for industrialized countries to stabilize or decrease their annual emissions of greenhouse gases. However, some sectors in Eastern Europe and the U.S.S.R. are also likely to increase CO₂ emissions still further. In the U.S.S.R., for example, there is only 1 car for every 25 people. In Poland and Hungary, living areas average 10 to 15

square meters per person as opposed to the U.S. average of 60.

Developing countries currently contribute at least one-third of greenhouse gases, mostly from land use changes and practices (e.g., tropical deforestation, rice cultivation, and livestock). But, CO₂ emissions will surely rise for developing nations still building an industrial base, just beginning to supply electricity to their people, and increasing the use of modern methods for cooking, heating, and transportation. Efficiency investments, while crucial to growth, can only decrease the need for new power; they can not eliminate it. Thus, if current trends continue, the greenhouse gas contribution from developing countries will grow quickly within a few decades to equal or exceed those from the developed world.

Social, cultural, and economic differences will be of paramount importance in any international negotiations that take place regarding climate change. For example, reductions in per-capita living standards (which reflect many of the above factors) are not a desirable policy goal, especially for countries that are well below the average. A goal for these countries is to decouple greenhouse gas emissions from desired economic growth. Conceptually, there are several ways to achieve this—switching to nonfossil fuels (e.g., solar, nuclear), increasing the efficiency of energy and materials use, reversing tropical deforestation, and implementing sustainable use of forest and agricultural resources. Moreover, no examination of the nature and dynamics of development, natural resource and energy use, and environmental protection can omit consideration of population growth nor, for that matter, issues such as foreign debt.

Options for the U.S. Congress are limited when dealing with the actions of other sovereign nations. However, Congress could directly encourage reductions in greenhouse gas emissions by adjusting aid policies and processes to take greenhouse gases into account. It could also encourage development and transfer of appropriate technology, encourage corporate ventures into nongreenhouse gas emitting technologies, and work towards adoption of international protocols.

³⁵These are actual or estimated expenditures and vary slightly from official authorizations. Total funding for population-related projects was slightly higher, because some family planning projects also are funded under other accounts.

The United States is the world's leading industrial society and largest single producer of CO₂. Major reductions of CO₂ and other greenhouse gases will require significant new initiatives by the Federal Government, the private sector, and individual citizens. The economic cost of these initiatives could be considerable. And many of these efforts must be sustained over decades.

OTA's analyses suggest that if the United States enacts a "Moderate" set of low-cost technical options, CO₂ emissions in 2015 will be about 15 percent higher than 1987 levels. If the United States enacts a "Tough" package, CO₂ emissions in 2015 could be as much as 35 percent below 1987 levels.

But, if the United States takes no action, emissions could increase by 50 percent in the next 25 years. This would continue the trend seen in the 1980s. Since the last two oil crises in the 1970s, concerted efforts to conserve energy have dwindled on all fronts—from government research and development to personal purchasing decisions. Many other goals diluted these efforts as energy prices dropped in the 1980s.

Now, as we begin the 1990s, several overarching issues loom on the horizon—energy insecurity, as demonstrated by the events in the Persian Gulf; domestic environmental problems as evidenced by numerous oil spills and persistent air pollution; global environmental degradation such as the Antarctic ozone hole, and tropical deforestation; and sustainable development as the Third World struggles to bring burgeoning populations into the industrial age and compete in world markets.

All of these concerns are difficult to control unilaterally, yet the changes they could induce in the average U.S. citizen's life over the next few decades may be profound. However, a common thread runs through these issues and can serve as an overall national goal—efficient energy use and conservation of natural resources. Ultimately, achieving this goal can help to sustain industrial output, competitiveness, and our overall quality of life. However, getting there will not be easy. Many of the options identified in this report can help move us in this direction while simultaneously reducing greenhouse gases.

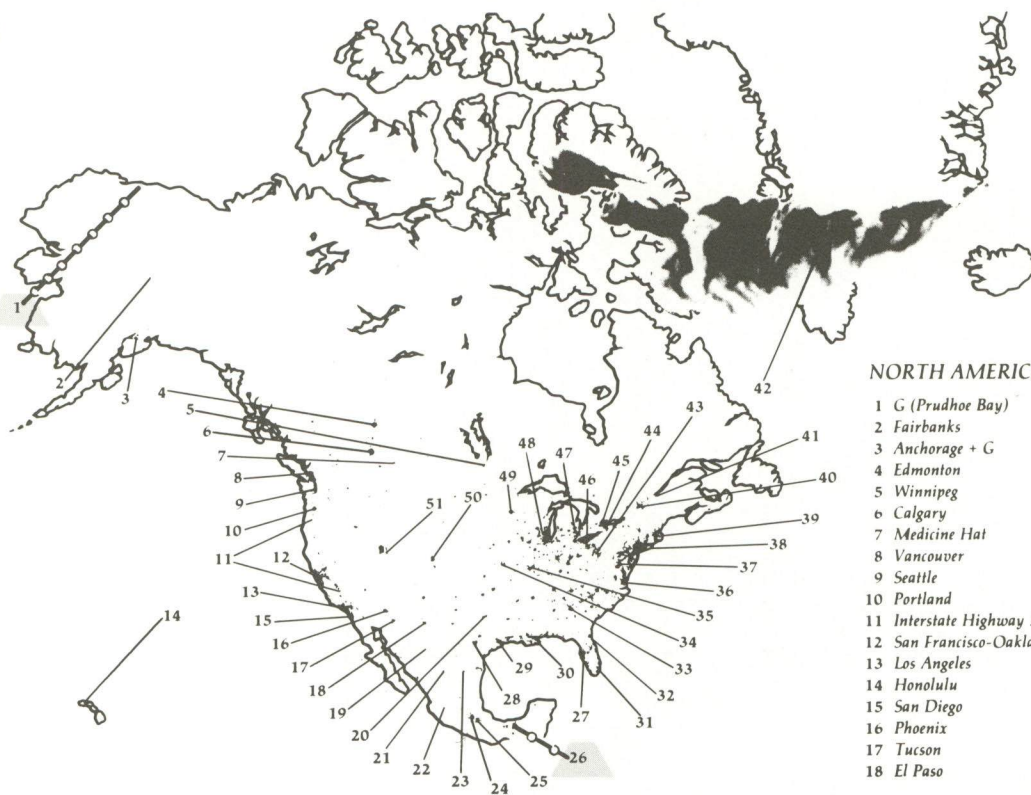
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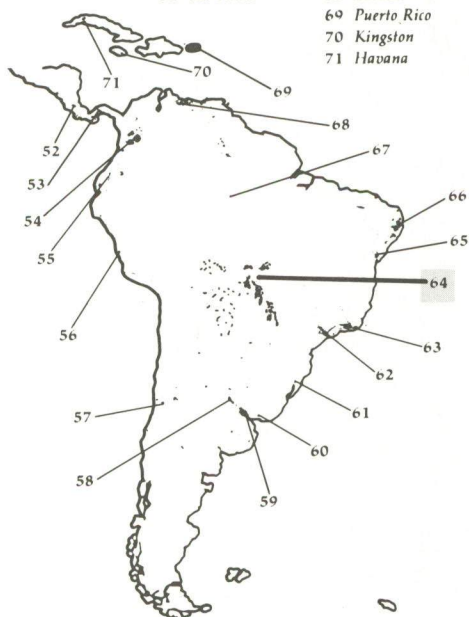


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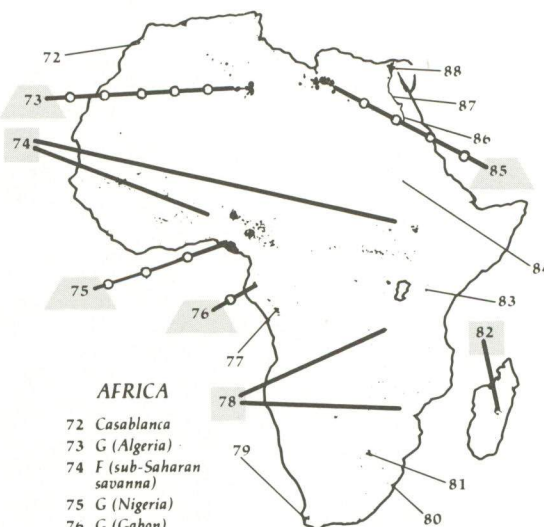
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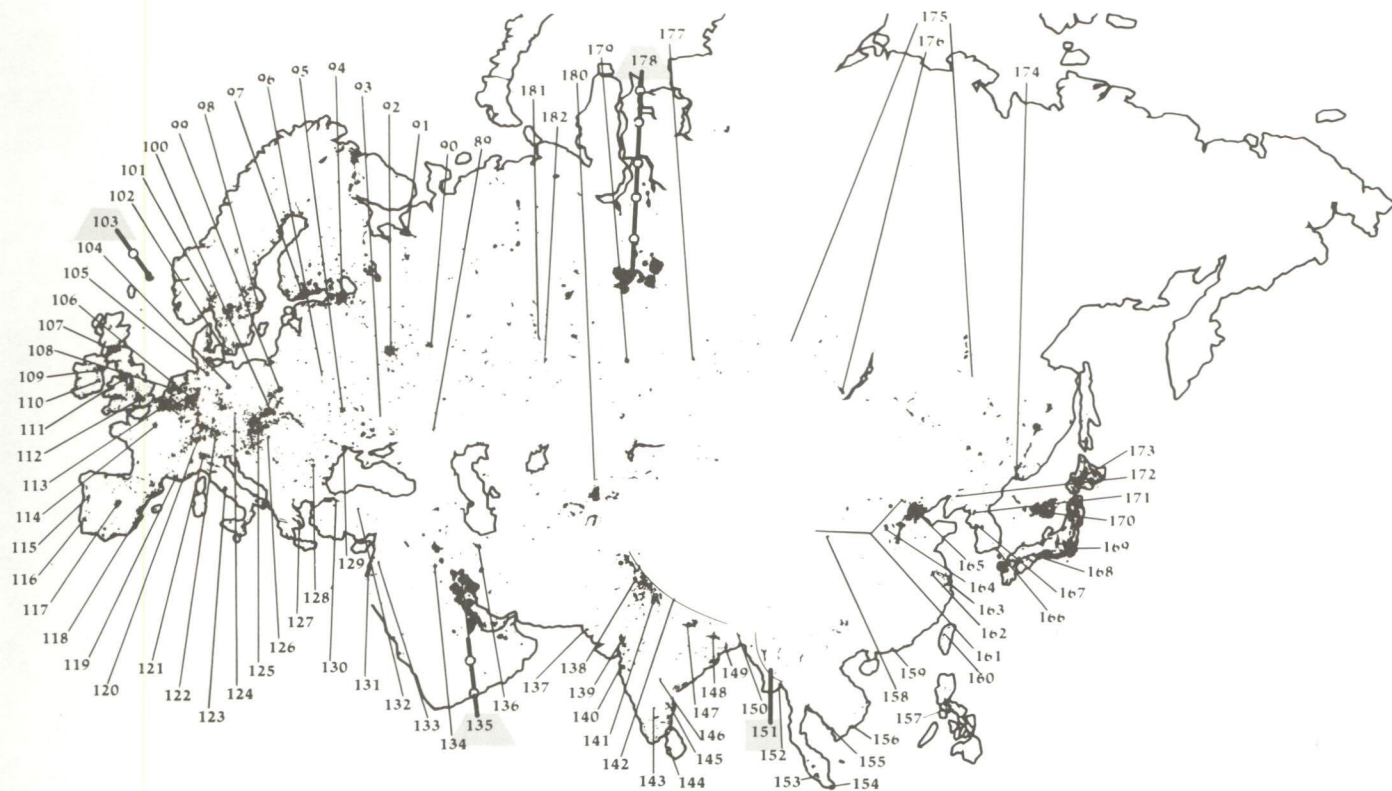
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| 55 | Quito + G | 60 | Montevideo | 66 | Recife |
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AFRICA

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| 73 | G (Algeria) | 85 | G (Libya) |
| 74 | F (sub-Saharan savanna) | 86 | Aswan |
| 75 | G (Nigeria) | 87 | Nile River |
| 76 | G (Gabon) | 88 | Cairo + Nile River delta |
| 77 | Kinshasa | | |
| 78 | F (Southeast Africa) | | |
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| 80 | Durban | | |
| 81 | Johannesburg | | |
| 82 | F (Malagasy [Madagascar]) | | |
| 83 | Nairobi | | |





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 140 Bombay
 141 Delhi
 142 Himalaya Mountains
 143 Bangalore
 144 Colombo
 145 Madras
 146 Hyderabad
 147 Allahabad
 148 Patna
 149 Calcutta + Ganges River delta
 150 Dacca
 151 F (SE Asian highlands)
 152 Rangoon
 153 Kuala Lumpur
 154 Singapore
 155 Bangkok
 156 Ho Chi Minh City (Saigon)
 157 Manila
 158 Lanzhou (Lanchow)
 159 Hong Kong
 160 Taiwan
 161 Jing-Bao/Bao-Lan Railroads + Yellow River
 162 Nanjing (Nanking)
 163 Shanghai + Yangtze River delta
 164 Taiyuan
 165 Beijing (Peking)-Tianjin (Tientsin)
 166 Pusan
 167 Seoul
 168 Osaka-Kobe-Kyoto
 169 Tokyo-Yokohama
 170 Japanese squid fleet
 171 Pyongyang
 172 Shenyang
 173 Sapporo
 174 Vladivostok
 175 Trans-Siberian Railroad
 176 Irkutsk
 177 Novosibirsk
 178 G (Surgut, Siberia)
 179 Omsk
 180 Tashkent + G
 181 Sverdlovsk
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FEBRUARY 1991

DRAFT

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STATEMENT OF E.U. CURTIS BOHLEN
Assistant Secretary of State for
Oceans, International Environmental and Scientific Affairs,
Department of State
United States of America
before the
Intergovernmental Negotiating Committee,
FRAMEWORK CONVENTION ON CLIMATE CHANGE

Thank you, Mr. Chairman. Ladies and Gentlemen, it is with great hope and enthusiasm that the United States joins in the start of negotiations on a framework convention on climate change. We are embarking on an ambitious international undertaking, a truly global effort to address what is perhaps the most complex and critical environmental issue we are likely to face for many decades to come. These negotiations are but the first step in what must be a sustained and long-term effort.

Climate change presents us with a dilemma of major proportions. Since the Industrial Revolution mankind has been engaged in an enormous unplanned experiment that is slowly changing the composition of the Earth's atmosphere. We cannot be certain what the result of this experiment will be, but we are fully aware that its consequences could be far-reaching. At the same time, the human activities that are affecting the atmosphere are fundamentally linked to all countries' economic well-being. We do not know what will happen if we modify these activities, but we recognize that there could be widespread economic impacts.

- 2 -

So we must determine what constitutes a responsible and sound international response to a global environmental concern in the face of a range of uncertainties. While this is not the first time we have been asked to make major policy decisions in the context of uncertainties, it may very well be the first time an issue of such complexity and with such broad ranging implications has been addressed by the full international community. We are clearly faced with unprecedented challenges to our wisdom, foresight, and scientific capacity.

The U.S. View of the Negotiations

The United States is entering these negotiations with the utmost seriousness of purpose. We have considered all aspects of this issue and brought to bear all of our experience and knowledge in environmental protection, scientific research, and economic decision making. Based on our deliberations, we will undertake these negotiations with several key principles in mind -- principles which we feel are the key to an effective convention and an effective global response to climate change:

- o First, we believe we must take a comprehensive approach to climate change, one which considers all aspects of this complex issue and which addresses all greenhouse gases and their sources and sinks;

- 3 -

- o Second, we must continue to pursue aggressively our scientific and economic research efforts and our technology development programs in order to resolve uncertainties and build a solid foundation for innovative responses;
- o Third, we must not wait for all uncertainties to be resolved, but must pursue cost-effective short-term actions - already justified on other grounds - which will limit net greenhouse gas emissions;
- o Fourth, we must adopt a long-term perspective which takes account of the costs and benefits of our actions for present and future generations; and
- o Fifth, we must recognize the special needs of the developing countries and design mechanisms for assisting them in securing the scientific and technical tools necessary for their fullest participation in a truly global effort.

We have the opportunity now to translate these principles into innovative and effective solutions by crafting a framework convention that will engage all nations in a concerted international response.

- 4 -

A Comprehensive Approach to Climate Change

The United States strongly believes an issue such as climate change can only be addressed effectively using a comprehensive approach, one which considers all sources and sinks of all greenhouse gases. A comprehensive approach to climate change will ensure that we take advantage of cost-effective opportunities to limit net emissions, that we do not create incentives to shift the problem from one type of pollutant to another, and that our research and technology development efforts address the many facets of the problem. A comprehensive approach also provides the flexibility needed for each nation to address climate change in the context of its unique circumstances.

The United States has established a strategy for addressing climate change that is comprehensive in scope and that provides for a sustained effort. One cornerstone of our strategy is a series of short-term actions that will result in U.S. greenhouse gas emissions in the year 2000 being equal to or below the 1987 level. Another is a more than \$2 billion program of global change research and energy technologies development that will provide us the tools for developing innovative long-term responses. We are providing you with a pamphlet, "America's Climate Change Strategy: An Action Agenda", which describes in detail what these actions are and what effect we expect them to have.

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unlike an and ensure that no nation will
be placed unnecessary at a certain a
conclusion disagreement*

- 5 -

Based on our extensive review of the climate change issue, we are convinced that a comprehensive approach offers the most effective framework for policy development. Accordingly, we believe the framework convention, and any subsequent legal instruments, must be comprehensive and deal with the full array of gases and their sources and sinks.

Actions that are Justified in Their Own Right

Another major goal of the framework convention should be to call upon all nations to undertake short term measures that are justified in their own right and that also have climate change benefits. As I have already noted, one cornerstone of the U.S. climate change strategy is a series of specific measures of this nature. These include:

- o eliminating ozone depleting compounds which are also strong greenhouse gases;
- o increasing forest greenhouse gas sinks;
- o directly controlling various greenhouse gases and their precursors which are also air pollutants;
- o reducing utility and other industrial emissions ^{by} ~~in a way~~ that ~~strongly encourages~~ energy efficiency;

by cost effective

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- 6 -

- o encouraging energy efficiency in such areas as buildings, appliances, and lighting; and
- o increasing the use of alternative fuels and renewable and non-fossil sources of energy.

Moreover, the United States is currently developing and will soon release a National Energy Strategy which will further contribute to greenhouse gas reductions through a long-term energy program that is economically sound, environmentally beneficial, and energy efficient.

We believe this approach should also be a centerpiece of the global response to climate change. It provides a realistic and cost-effective framework under which all countries can begin to implement measures with climate change benefits. At the same time it recognizes that the appropriate measures available to different countries will vary depending on their social, environmental, and economic circumstances.

Research and Monitoring

If one takes the long term perspective on climate change, it becomes evident that research into all aspects of the issue is absolutely crucial. Research and monitoring are essential to improving our understanding of climate change and helping us

- 7 -

to tailor responses that are appropriate, effective, and sustainable over the long term. Our research efforts will also provide the needed energy efficient technologies that will be both economic and environmentally beneficial. A strong program of research and monitoring must thus be another cornerstone of the framework convention.

The United States will propose specific areas for research and monitoring, analysis, and information exchange. We believe the framework convention should focus research on reducing uncertainties associated with changing concentrations of greenhouse gases; sources and sinks of greenhouse gases; clouds and radiative balance; oceans; land surface hydrology and vegetative processes; ice sheets and sea level change; ecological dynamics; trace gas indices; and impact assessments. Such a research agenda would address the significant scientific uncertainties regarding the potential timing, rate, magnitude, and regional impacts of climate change.

To improve our understanding of the consequences of climate change, and to give us confidence in designing effective responses, the framework convention should also establish a strong international economic research effort. This research should be structured around the following themes:

- 8 -

- o the economic forces related to global environmental change;
- o the costs and benefits and social/economic impacts of climate change;
- o the value of information and decision-making under uncertainty;
- o mitigation and adaptation strategies; and
- o economic forces shaping technology and practices relevant to global environmental change.

Our research efforts must, to the extent possible, involve all countries, both developed and developing. We can ensure that this occurs by redoubling our efforts in existing programs, including those of UNEP, WMO, IOC, ICSU, OECD/IEA, and the World Bank. We support expanding and restructuring the World Climate Program to coordinate research and monitoring in support of the framework convention. We also note that the WMO's Climate Studies Fund provides for developing country participation in the global observing system, which is needed to advance our understanding of climate.

In addition, the framework convention should require the full and open exchange of scientific, technical, and economic data and information related to climate change. Without a universal pool of information, there will be unnecessary duplication of efforts, as well as the creation of critical gaps in the research program. By fostering adequate data

- 9 -

exchange, the convention can also help to reduce differences in the diverse methods for measuring net emissions and emission uptake rates.

Implementation Issues

There are many other specific issues that must be addressed prominently in the framework convention. With regard to the developing countries, we all recognize their desires and aspirations for economic growth and the importance of a truly global response to climate change. We believe the framework convention should include a general commitment to promote financial assistance to developing countries to study and address climate change. Depending upon the particular circumstances, both existing financial assistance mechanisms and the newly established Global Environmental Facility in the World Bank may be appropriate mechanisms for processing such multilateral assistance.

Technology transfer is essential to a global response and there are many existing low cost technologies that can be transferred now. We are prepared to explore a number of ideas including energy efficiency centers, demonstration projects, and industry joint venture maintenance projects. Implementation of these concepts will need to be considered, of course, in the context of specific commitments to action, and special efforts will need to be made to match appropriate technologies to needs.

- 10 -

Over the long term, new technologies will play an increasingly important role in the response to climate change. Many of these technologies are still only ideas, or must undergo further development to become feasible. Thus, the convention should provide the right incentives for the continual research, development, and dissemination of appropriate technologies. Furthermore, to promote the creativity and entrepreneurship that have fostered technology development in the past, the convention should seek to remove barriers to effective commercial development and transfer of technology and should ensure that intellectual property rights are fully protected.

We should also discuss ways to transfer the knowledge necessary to understand, plan for and address climate change. The United States has traditionally provided a great deal of technical assistance in dealing with specific environmental problems, developing environmental institutions, and conducting country studies. We are prepared to do more, both individually and working with other countries. The NGO community, including the business community, also has an important role to play in this regard.

A final issue we must consider is the need for a global effort to promote public awareness and knowledge of climate change. Because both climate change and the responses to

- 11 -

it may affect - either directly or indirectly - almost every sector of society, broad public awareness and participation is needed. The dissemination of information also represents a powerful instrument for promoting the development and use of new technologies and ensuring that markets accurately take into account the potential consequences of climate change.

Conclusion

In conclusion, Mr. Chairman, let me reiterate that we have set for ourselves a goal of no small significance. We are seeking to negotiate a framework convention on a issue of unprecedented dimensions in a relatively brief time. Let us begin then by focussing on those areas where we can reach agreement over the next year, starting at this session with electing a bureau, rapidly completing our organizational work, and preparing an initial draft text. We can in the short time before the 1992 U.N. Conference on Environment and Development craft an effective framework convention that will move the international community closer together in our common goal of protecting the global environment.

Finally, let me express on behalf of the U.S. delegation our gratitude for the hard work of all our colleagues in preparing for these negotiations. In particular we would like to thank Professor Obasi, Secretary General of the WMO, and Dr.

- 12 -

- Tolba, Executive Director of the UNEP, for the support they have provided on behalf of their organizations and in the context of the Intergovernmental Panel on Climate Change. We now look forward to working closely with all the delegations here in what we are confident will be a productive first round of talks.

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United States Department of State

Washington, D.C. 20520

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TRANSMITTED BY:

Joan Donoghue

Assistant Legal Adviser for Oceans, International
Environmental and Scientific Affairs

Department of State

Office of the Legal Adviser

Room 6420

Telephone: (202) 647-1370

Fax: (202) 647-1037

COMMENTS:

Doc is along a paper but has
not yet seen it as is. I'd suggest
you call Jonathan.

Framework Convention on Climate Change:
Dispute Settlement Provisions

Issue

Whether the United States should propose that the framework convention on climate change provide for compulsory and binding dispute settlement.

Discussion

Consideration should be given to whether it would be in the USG interest to support compulsory, binding dispute settlement where negotiations have failed to resolve a dispute. From a substantive point of view, a compulsory/binding dispute settlement approach could be beneficial to USG interests:

- o such an approach would provide a mechanism that could be used as a handle for enforcing the convention's obligations against those states that are not in compliance, thereby avoiding the "legal safehaven" problem that has led to criticism of Montreal Protocol;*/

- o as applied to the framework climate change agreement, such an approach would not pose a threat to USG interests in that the U.S. has been scrupulous about only becoming party to environmental agreements that it can implement and about faithfully implementing those to which it is party.

From a negotiating strategy point of view, such an approach could have certain advantages, even if it were not to be ultimately accepted:

*/ The consequence of not requiring binding dispute settlement can be the creation of a "legal safehaven" for states in non-compliance. In the context of the Montreal Protocol, for example, a state, in order to evade the imposition of trade controls against it for being a "non-Party", could become a party to the Protocol and not comply with its obligations. Assuming that the state had not, upon becoming a party, declared its acceptance of either the International Court of Justice or binding arbitration, it would be subject only to being brought before a conciliation commission, which could only issue a non-binding award. The supplementary "non-compliance procedures" adopted under the Protocol would also lead, at most, to a recommendation to the Parties for further action.

- 2 -

o the prospect of binding and compulsory dispute settlement might constrain far-reaching substantive proposals of other states (particularly those relying on the absence of enforcement mechanisms);

o if the USG were to insist on such an approach, it might be able to get something in return for eventually dropping such insistence.

The United States has accepted compulsory and binding dispute settlement in other environmental agreements (for example, the Antarctic Minerals Convention and MARPOL). Other approaches to dispute settlement include:

(1) optional resort to a third party for a binding decision (see, for example, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, ECE Convention on Environmental Impact Assessment in a Transboundary Context);

(2) compulsory resort to a third party for a non-binding decision;

(3) a combination of (1) and (2), i.e., if a party does not opt for resort to a binding decision, then it would have to submit the dispute to a non-binding procedure (see, for example, Vienna Ozone Convention, which also applies to the Montreal Protocol).

Optional resort to binding decision can create disparate obligations. If the United States accepted the optional mechanism, for example, it could be taken to binding arbitration. Meanwhile, the United States would have no legal recourse against governments that are parties to the convention but that have not accepted the optional mechanism. (Optional resort is favored, however, in situations in which the nature of the obligations suggests that the United States would be unwilling to submit questions of its compliance to third-party resolution, e.g., where disputes would relate to armed conflict).

Unlike traditional environmental issues, where there is a particular injured state (e.g., an illegal shipment of hazardous wastes under the Basel Convention), in the context of a global issue such as climate change, it is likely that the injury that results from a breach of the agreement would be generalized. Thus, a dispute settlement mechanism could be structured so as to give standing to any party to enforce the agreement's terms. The mandate of the arbitral tribunal should extend to the determination whether there has been a breach of

- 3 -

the convention, including the ascertainment of any facts necessary to make that determination. In the context of climate change, however, it might be advisable not to extend the mandate of the arbitral tribunal to determination of damages. This is the approach that the United States is taking in the Antarctic environment protocol, in which, as in climate, the harm caused by a breach is generalized.

In keeping with recent United States practice, the United States would provide that parties could choose to submit disputes either to an arbitral tribunal or to the International Court of Justice, but that disputes would be referred to the arbitral tribunal unless both parties had chosen to submit disputes to the International Court of Justice.

If a protocol or protocols containing specific targets and timetables are later concluded, consideration can be given then to extending the convention's dispute settlement regime to such protocol(s), or whether compliance with the obligations contained in the protocol(s) is better addressed through other means.

Recommendation

That the United States propose that the climate change convention provide for compulsory and binding dispute settlement. The competence of the decision-maker would extend to determining whether there has been a violation of the convention but not to the assessment of damages. The convention would provide that the dispute settlement provisions could apply to a subsequent protocol, to the extent that the protocol so specified.

Drafted:L/OES:JEDonoghue

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET

ROUTE SLIP

TO Jeff Miotka

Take necessary action	_____
Approval or signature	_____
Comment	_____
Prepare reply	_____
Discuss with me	_____
For your information	_____
See remarks below	<u>X</u>

FROM Norman Hartness *NH*

DATE January 18, 1991

COMMENTS ON DISPUTE SETTLEMENT PROVISIONS:

We strongly oppose any provision for compulsory and binding dispute settlement as a part of the framework convention on climate change. The U. S. position on the substance of that convention is that it should include only general obligations. Since that is so, no dispute provisions are required for the convention.

If there are subsequently negotiated any protocols which have obligations that would require dispute settlement provisions, the nature of these provisions can be addressed as a part of negotiating the protocol(s).

The only purpose that occurs to me of having dispute settlement provisions in the convention would be to establish a precedent which would tend to bias the outcome of dispute settlement discussion in future protocol negotiations. It is not at all clear that biasing such future discussions toward compulsory and binding provisions would be desirable.



Department of Energy
Washington, DC 20585

JAN 16 1991

MEMORANDUM FOR: Daniel Raifenyder
U.S. Department of State
OES/OGC

FROM: Denise Dwyer 
U.S. Department of Energy
IS-141

SUBJECT: DOE Comments on Papers on Dispute
Resolution and Subgroups

We offer the following comments on the two issues papers provided at last week's FCC Working Group meeting.

Dispute Resolution:

DOE is opposed to the recommendation in this paper that the United States propose that the climate change convention provide for compulsory and binding dispute settlement.

We oppose this approach on several grounds:

- o We are not yet sure of the general and specific obligations which will be included in the convention. It would be unwise to propose compulsory and binding resolution until the nature and interpretation of any such obligations is clarified. Such clarification may have to be referred to technical subgroups set up to support the convention process.
- o The USG may not be in a position to meet binding and compulsory settlement even in regard to very general obligations, unlike some other countries whose climate change policies and plans are more directly government-controlled. For instance, how would the U.S. comply with a binding resolution that it has not met a general obligation to develop a "national strategy to reduce greenhouse gas emissions" if: (1) such a strategy has not been approved within the USG or; or (2) if, in spite of such a strategy, US greenhouse gas emissions are rising? Similarly, how could the USG subject itself to binding and compulsory resolution if a developing country contends that the U.S. is not meeting a general obligation such as a requirement for "rapid transfer of environmentally sound technology to the developing countries on preferential terms"?

- o What would be the legal liabilities vis-a-vis U.S. companies if the USG is subject to binding and compulsory resolution over issues or activities which are more in the purview of the U.S. private sector?
- o We do not agree with the argument in favor of this approach in the State paper that "...the prospect of binding and compulsory dispute settlement might constrain far-reaching substantive proposals of other states (particularly those relying on the absence of enforcement mechanisms)". To the contrary, the prospect of binding and compulsory resolution could lead to escalation of developing country demands for additional financial assistance and technology transfer on non-commercial terms; and it may not be as effective as we think in discouraging other industrialized countries from proposing CO2 controls in the convention, since many of these countries are planning to implement such reduction plans. As you will recall, Japan is pushing for a "pledge and review" system to review CO2 reduction programs.

We have consistently argued that the convention should be general in nature, laying out research and information exchange requirements and only very general obligations. Binding and compulsory resolution on such provisions does not appear warranted or suitable at this stage. Such an approach might be advisable in the context of subsequent control protocols.

We request that the dispute resolution provisions in the convention be those used for the Vienna Convention on the Protection of the Ozone Layer. As provided in Article 11 of that Convention, these provisions provide for:

- o First, seeking solution of a dispute by negotiation between the disputing Parties;
- o Second, failing resolution through such negotiation, a joint request for mediation by a third party;
- o Third, failing resolution by these means, an indication in writing by the parties that they accept compulsory resolution of the dispute by one or both of the following procedures: arbitration in accordance with the Conference of the Parties at its first ordinary meeting; submission of the dispute to the International Court of Justice;
- o Fourth, failing acceptance of any of the above, submission of the dispute to a conciliation commission to be created upon the request of one of the disputing parties and whose finding shall be considered in good faith by the parties.

This approach would be favored for the purposes of the convention in that it would be:

3

- o More in keeping with the general nature of the convention;
- o Reserve consideration of the advantages of binding/compulsory dispute settlement in subsequent protocols;
- o Encourage wider participation by countries in the convention, particularly those developing countries who will be hesitant to submit to binding arbitration when their knowledge of the issues and national capabilities to respond are limited.

Subgroups:

We have two general problems with this paper:

- o It does not address the role of the IPCC and how the IPCC structure would be utilized to support the negotiations process and, eventually, integrated into the negotiations structure;
- o It does not appear feasible to separate Greenhouse Gases: Their Sources and Sinks as a subgroup separate from the subgroup being proposed on scientific and economics research, monitoring and information exchange.
- o We disagree with the position stated that the U.S. should not take the lead in naming subgroups but only support proposals that provide the broadest context for addressing the climate issue in a comprehensive fashion.

We would suggest that the following subgroups be considered:

- o Science and Economics Research Issues: To address priority areas for scientific and economics research and information exchange. This group could address: research needs to improve global circulation models, the GWP index, economic impact assessment of climate change and responses to it; existing scientific and economics research capabilities and any infrastructure requirements and new funding requirements. This group would elaborate on the research requirements to be included in the Convention.
- o Data, Monitoring and Information Requirements: This group could assess trends in greenhouse gas emissions and sinks; existing data sources; new data requirements; monitoring capabilities and needed improvements. This group could elaborate on the monitoring and information exchange provisions to be included in the Convention.

- o Implementation Issues as described in the State Department paper.
- o Legal Issues. This might have to be more than a drafting committee, as indicated in the State paper. For instance, the Vienna Convention includes provisions for exchange of relevant commercial and legal information. The group on legal issues could examine similar needs in the context of the climate change convention. However, we agree that its primary focus would be to prepare the text, based on inputs from the negotiating session.

It should be made clear that the scope of all subgroups is all greenhouse gases, both their sources and sinks. Consistent with the approach developed in the report of the Justice Task Force, the comprehensive approach would then be applied to all aspects of the process.

We do strongly support the position in the paper that the USG oppose the establishment of sector specific subgroups, such as groups on energy and forestry.

REVISED DRAFT 1/24/91

A COMPREHENSIVE APPROACH TO ADDRESSING POTENTIAL CLIMATE CHANGE

A Report of the Interagency
Task Force on
Comprehensive and Incentives Approaches
to Climate Change

January 1991

U.S. Department of Justice
Environment & Natural Resources Division
Washington, D.C.

A COMPREHENSIVE APPROACH TO ADDRESSING POTENTIAL CLIMATE CHANGE

A Report of the Interagency Task Force on Comprehensive and Incentives Approaches to Climate Change

Table of Contents

<u>Section</u>	<u>Title</u>	<u>Page</u>
Overview:	An Outline of Key Points	1
Chapter I:	The Setting	11
Chapter II:	The Science of Climate Change	16
Chapter III:	Defining a Comprehensive Approach	30
Chapter IV:	A Comprehensive Approach to Research and Monitoring	39
Chapter V:	Environmental Advantages of a Comprehensive Approach	44
Chapter VI:	Economic and Institutional Flexibility	58
Chapter VII:	Potential Objections and Replies	69
Chapter VIII:	Market-Based Incentives	76
Conclusion:	Toward a Comprehensive Approach	91

This Report is the product of an interagency task force of the United States Government. The "Task Force on Comprehensive and Incentive Approaches to Climate Change" was organized in May 1990 to define and develop the comprehensive approach. The Task Force is an interagency effort with representatives of CEA, CEES, CEQ, DOC/NOAA, DOE, DOI, DOJ, DOT, EPA, NASA, NSF, OPD, OSTP, State, USDA, USTR, Treasury, and WH Counsel. It is chaired by the Department of Justice, Environment & Natural Resources Division. Comments on this Report, and requests for additional copies, should be sent to the attention of Jonathan Wiener, Environment and Natural Resources Division, U.S. Department of Justice, Room 2143, 10th & Constitution Avenue, N.W., Washington, D.C. 20530.

A COMPREHENSIVE APPROACH
TO ADDRESSING POTENTIAL CLIMATE CHANGE

OVERVIEW: AN OUTLINE OF KEY POINTS

As negotiations on a Framework Convention on Climate Change begin, it is timely to consider the best approach to addressing potential human-induced global climate change in a convention and in possible subsidiary instruments. We know from experience that the success of environmental policy instruments and institutions is critically related to their design. If law fails to match the environmental system to which it is addressed, the results are frustrating failure and dysfunction. It is crucial that careful attention be given to the question of how best to match the structure and content of any international agreement to the science and economics of human interactions with climate.

The best design for the climate change convention, and for any policy responses, would be a "comprehensive" approach that addresses all relevant trace gases, their sources and sinks. In August 1990, the Intergovernmental Panel on Climate Change (IPCC) included in its Overview the statement: "A comprehensive strategy addressing all aspects of the problem and reflecting environmental, economic and social costs and benefits is necessary." In November 1990, the government ministers at the Second World Climate Conference (SWCC) declared: "We recommend that in the elaboration of response strategies, over time, all greenhouse gases, sources and sinks be considered in the most comprehensive manner possible..."

A comprehensive approach is needed in order to deal with all of the many the scientific, environmental and economic aspects of the climate system, which involves many trace gases affected by activities in every sector of human society. From the point of view of environmental quality, the focus of interest is the combined effect of all the greenhouse gases on the environment. A "piecemeal" approach, focusing narrowly on only one aspect of the system such as one greenhouse gas, would be scientifically inadequate, environmentally ineffective, and economically inefficient. It would repeat the mistakes made in many traditional environmental policies over the last two decades.

In contrast, under a comprehensive approach, all greenhouse gases, their sources and sinks are addressed together. The result is more coherent understanding of the factors contributing to potential global climate change, and more effective and efficient design of any policies to address those

factors. In order to address all greenhouse gases together, a comprehensive approach employs a measure, such as an "index," to compare the contributions of different gases to total global climate change. A comprehensive approach also employs the concept of "net emissions," taking into account the uptake of gases by sinks as well as their release from sources.

A comprehensive approach thus addresses all of the anthropogenic factors contributing to potential climate change. It assembles the elements needed for a full understanding of potential climate change, and helps identify the areas most in need of further research. As we urgently press ahead, through the framework convention, to improve scientific and economic understanding of global change, a comprehensive approach is essential to advancing worldwide knowledge, research, and measurement of the climate system and of human interactions with climate. A comprehensive approach is critical to any effort to forecast the potential for future climate change associated with human emissions of trace gases.

The comprehensive concept is an "approach" or heuristic that offers insight into any discussion of response strategies for potential climate change. The utility of the approach is not limited to the design of emissions limitation policies; it is the proper framework for pursuing scientific research, developing technology, or evaluating current policy actions. It chiefly suggests how to design sound policies, not how much to respond.

In addition, if measures to prevent climate change are warranted, a comprehensive approach would be the most environmentally effective as well as economically efficient design. By addressing all the human-influenced factors in potential global climate change and using an index of relative impacts, a comprehensive approach maximizes the environmental value of every investment in greenhouse abatement. It highlights and avoids the shifts by economic actors from regulated to unregulated activities that will likely occur under narrowly aimed piecemeal policies; these shifts can undercut or even reverse the benefits of the piecemeal measure. The comprehensive approach encourages the use of the most innovative and resource-efficient responses, including efforts to conserve and expand greenhouse gas sinks, such as forests, with related benefits. Furthermore, because each nation has a different economy, society, and portfolio of greenhouse gas sources and sinks, the best set of response measures will be different for each nation; a comprehensive approach provides the needed flexibility for each nation to develop its most cost-effective mix of measures to fit its particular domestic needs while achieving global results.

"Comprehensive Approach" described

- o It is an approach to structure consideration of climate change issues -- scientific, economic and policy -- on a comprehensive basis, addressing all the human interactions with the climate system.
 - o It stands in contrast to the "piecemeal" approach currently dominating discussion, which focuses narrowly on emissions of one gas, carbon dioxide (CO₂), primarily from the energy sector, and omits other critical factors.
 - o It considers all of the significant human-influenced "radiatively active trace gases" (RATGs) that affect climate:
 - Carbon dioxide (CO₂)
 - Methane (CH₄)
 - Nitrous oxide (N₂O)
 - Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs), and related substances
 - Tropospheric Ozone (O₃) and its precursors:
 - Nitrogen oxides (NO_x)
 - Carbon monoxide (CO)
 - Volatile organic compounds (VOCs or NMHCs)
 - o It considers all sources and sinks (such as forests and oceans) of the relevant gases, in every sector of human activity:
 - Energy production
 - Transportation
 - Agriculture
 - Forestry and land clearing
 - Industry
- It focuses on "net emissions" (sources less sinks), the important variable for determining atmospheric concentrations.
- o A comprehensive approach is in use in other areas:
 - The Montreal Protocol's use of an Ozone Depletion Potential (ODP) index to phase out CFCs and related substances
 - "Multimedia" approaches to integrated management of land, air, and water pollution.

Comparing trace gases

- o A comprehensive approach 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 environmental characteristics:
 1. Heat trapping ability ("radiative forcing")
 2. Residence time in the atmosphere
 3. Reactivity with other gases (affecting both the gas' own residence time and the production of other radiatively active trace gases)
 4. Other attributes, such as ozone depletion or plant fertilization.
- o One possible index is the "Global Warming Potential" (GWP) index of "radiative forcing," presented in the IPCC Report:

Gas	Instantaneous radiative forcing per kg (rel. to CO2)	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, 1990, Tables 2.3, 2.8.)

- o Use of an index provides a guide to environmentally optimal choices, maximizing the environmental value of each investment of society's resources. It also helps ensure that decisions are not made that limit one gas while ignoring and inadvertently increasing others.
- o Use of an index also allows flexibility to design a mix of measures addressing the various gases, toward any overall goal.
- o Some index or weighting system is unavoidable, whether implicit or explicit. A CO2-only policy implicitly weights the other gases at zero.

A Comprehensive Approach has multiple applications

- o Research. Designing research strategies to improve understanding of all relevant gases, sources, sinks, and source/sink processes. Many are not yet sufficiently well understood and require significant study. Development of trace gas indices, and integrated science/economics research, should also be pursued.
- o Monitoring and Inventories. Calculating current atmospheric concentrations and net emissions for all relevant gases by nation and sector. Today the ability to measure sources and sinks of several trace gases, such as N₂O and CH₄, and to measure sinks of CO₂, is incomplete.
- o "Report cards." Calculating the likely effects of current policy actions on net emissions of all relevant gases. This task depends on reliable forecasts of trace gas emissions trends, which also require a comprehensive approach.
- o Technology evaluation. Calculating the effects on net emissions for all gases of technologies and practices. Possible uses in technology transfers, financial assistance, R&D funding.
- o Policy choices. Calculating the effects on net emissions of proposed policy actions. The comprehensive approach provides a powerful analytic tool for evaluating piecemeal policy proposals.
- 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.

The policy context of a Comprehensive Approach

- o The comprehensive concept is an "approach" or heuristic that offers insight into any discussion of response strategies for potential climate change. The utility of the approach is not limited to the design of emissions limitation policies; it suggests the proper scope and optimal design for pursuing scientific research, developing technology, evaluating current policy actions, or designing emissions limitations policies (whether domestic or international).
- o It chiefly considers how to design sound policies, not how much to respond, though it does shed light on the latter question by focusing analysis on the full environmental benefits and economic costs of potential actions.

Advantages of a Comprehensive Approach

A. Environmental advantages

- o Piecemeal policies have often proved environmentally ineffective or even counterproductive. Historically, environmental policy design has been piecemeal: efforts have been aimed separately at emissions into the air, water, and land "media." This piecemeal approach has led to "cross-media shifts" in "residuals" (emissions and wastes), moving pollution around without reducing it.
- o Piecemeal pitfalls: 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 would 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 the resulting increased methane (CH₄) emissions from leakage of natural gas facilities. At a CH₄ leakage rate of about 6%, roughly all of the CO₂-related reduction in radiative forcing from the coal-to-gas fuel switch is offset by CH₄ leaks. (Rodhe (1990), using a 100-year GWP; not counting CH₄ venting from fuel extraction.) Since CH₄ leaks are thought to average about 2-4% worldwide, about half the CO₂-related savings would be offset. And CH₄ leaks may average 5-10% in the Soviet Union, where coal-to-gas switching under a CO₂-only emissions limitation could actually increase net radiative forcing.
Moreover, capturing fugitive CH₄ emissions might be a highly cost-effective means of limiting contributions to radiative forcing, especially where leakage rates are high. A CO₂-only policy ignores that option.
 - Piecemeal focus on limiting agricultural CH₄ from wet rice farming could induce use of nitrogenous fertilizers that reduce CH₄ emissions per rice yield, but also raise N₂O emissions.
 - Piecemeal focus on a subgroup of emitters, such as only a few nations, would omit major sources of future emissions, and would be undercut by shifts in emissions-intensive activities to other nations.

A comprehensive approach ensures that policy makers are aware of and account for such shifts.

Advantages, continued

- o Optimal signals. A comprehensive approach would provide optimal incentives in any efforts, if warranted, to develop new technology or limit emissions. It maximizes the environmental benefit from any investment of social resources. It provides an environmentally sound guide to selection of technologies for development and transfer, or to enacting incentive policies, across the entire range of socioeconomic activities affecting trace gas net emissions.
- o Inclusion of Sinks. By focusing on "net" emissions, the comprehensive approach fosters sink protection and expansion, such as afforestation and protection of carbon-fixing phytoplankton. Benefits may include biodiversity, reduced soil erosion, and protected food webs. (Management of sinks is a complex endeavor, and poorly designed sink enhancement policies could have adverse impacts.)

B. Economic and social advantages

- o Piecemeal approach is economically inefficient. Piecemeal policy would exclude policy options that address other gases, other sources, or sinks, and could achieve the same environmental outcome at less cost. For example, a policy aimed only at energy sector CO₂ would bar potentially less costly yet equally effective abatement options such as enhancement of CO₂ sinks, CH₄ reductions, faster CFC reductions, and attention to CFC-substitutes.
- o Flexibility reduces costs. Because each nation has a different economy, society, and set of sources and sinks, the costs of different options will vary across gases and sectors and across nations. While limiting CO₂ emissions from energy might be best for one nation, limiting CH₄ emissions from waste disposal (or rice or livestock) might be best for another, afforestation best for a third, and reducing tropospheric ozone precursors best for another. Requiring them all to take the same action would impose needless costs. Affording each nation the flexibility to design its best policy mix to address the various gases, sources and sinks helps minimize the economic costs and institutional dislocations of any emissions limitations.
- o Level Playing Field. A piecemeal approach inevitably favors some nations while disproportionately burdening others. For example, a CO₂-only approach penalizes nations with relatively greater dependence on fossil fuels or fossil fuel revenues. A comprehensive approach provides a "level playing field" across nations, increasing the likelihood of cooperation.

Potential Objections to a Comprehensive Approach, and Replies

- o "Data and monitoring of sources and sinks are inadequate."
 - Better data and monitoring are being pursued, and this work needs to be accelerated. The convention should advance international cooperation in this effort.
 - Where direct measurement is impractical, carefully chosen proxies or surrogates can be employed.
 - Incentives could spur monitoring improvements, such as offering rewards to those who develop and demonstrate better monitoring techniques.
 - The groundwork needed to flesh out a workable comprehensive approach is very likely to be less costly than the environmental and economic losses due to a piecemeal approach that is ineffective and inflexible.
- o "The Global Warming Potential Index is uncertain."
 - There is emerging international consensus that the scientific fundamentals are sound.
 - Uncertainties will be reduced as methods, data and estimates improve.
 - Absolute precision is not necessary for practical uses.
 - Some weighting system is unavoidable.
- o "Other discrete actions will have already been taken, such as the forthcoming forestry agreement, limits on CFCs in the Montreal Protocol, and 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 trace gas emissions but are taken for other reasons.
- o "CFCs should not be included in comprehensive basket."
 - All substances contributing to radiative forcing should be included. For example, CFCs and CFC substitutes (HCFCs, HFCs) may be quite important to radiative forcing. The Montreal Protocol does not account for these impacts.
 - Comprehensive approach would not allow violation of the Montreal Protocol. Reductions more ambitious than required by the Protocol could earn credit.
 - Some nations are doing more to reduce global CFCs than others, and their contribution should be recognized.
 - 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.

Objections and Replies, continued

- o "A comprehensive approach is complex and unworkable."
 - Experience shows that a comprehensive approach need not be complex or unworkable. The Montreal Protocol successfully employs a multi-gas approach with an ODP index.
 - As experience with traditional environmental issues shows, piecemeal approach means scrambling to redress unintended shifts and dysfunctions.
 - Comprehensive approach eases workability by affording nations needed economic and institutional flexibility.
- o "We can't afford to wait for a comprehensive approach; we need to do what we can now to address CO2."
 - Development of a comprehensive approach does not mean delay. A comprehensive approach can be phased in as other actions (e.g. forestry agreement), and harder-to-monitor sources and sinks, are integrated.
 - But the framework needs to begin as a comprehensive approach; experience shows that once a piecemeal approach is adopted, interests favored by its narrow scope become entrenched and a sound approach is blocked.
 - Given its environmental and economic advantages, taking the time to develop a comprehensive approach is worthwhile. Hasty resort to a piecemeal approach would achieve less overall environmental gain than fashioning a sound comprehensive approach.
 - By sharing burdens on a level playing field, a comprehensive approach eases the route to consensus; a piecemeal approach imposes disproportionate burdens that will generate resistance.
 - A comprehensive approach makes better use of scarce resources. It thus better provides for sustainable development, which requires both effective and efficient policies since environmental protection ultimately depends on the resources that economic growth provides.
 - A comprehensive approach does not prevent action. Nations who wish to limit net emissions of any of the range of trace gases may do so now; indeed taking a comprehensive approach broadens the set of opportunities to address potential climate change.

Options for Including a Comprehensive Approach in a Framework Convention. As described earlier, the comprehensive approach has multiple applications. Each could be incorporated into the work of the IPCC, the convention, and any program the convention establishes. For example, the convention could charge the IPCC or other body to coordinate and assess work on the following:

- (1) Research strategy. Pursue integrated 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 techniques and systems for comprehensive source and sink monitoring: cooperative international networks measuring emissions and uptake of all relevant trace gases. Establish centers 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: base-line levels and changes due to policy actions. Provide for national reporting, workshops to compare data and methods.
- (4) Indices. Cooperative development and refinement of indices. The IPCC or other expert body could conduct regular assessments and keep policy makers informed of developments.
- (5) Technology evaluation. Employ a comprehensive approach to assess the net emissions impact of any technology transfer and financial assistance activities.

The convention could also:

- (6) Ensure a comprehensive framework for 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 the convention.
- (7) Offer incentives through advance assurance. Give advance assurance that current actions will receive "credit" against any future obligations, in accordance with a comprehensive approach. This would help avoid disincentives to taking actions justified on other grounds, which nations may hold in abeyance until credit for them is assured. Actions could include afforestation, energy conservation, and trace gas reductions, and both national and international programs.

Chapter I: The Setting

Negotiations are beginning on a "framework convention on climate change." Following the report of the Intergovernmental Panel on Climate Change (IPCC) in August 1990, in particular its paper on legal measures, the convention is likely to contain provisions relating to scientific research, monitoring, information exchange, economics research, and other issues of importance to the negotiating parties. At the same time, the IPCC considered, and some have urged, adoption of response measures to mitigate or adapt to potential climate change.

Any analysis of important events and outcomes requires understanding the underlying systems at work and the interrelationship of the variables that make up those systems. One cannot look only at isolated events or outcomes and expect to understand the complex system as a whole. As the conservationist John Muir put it, "when we try to pick out one thing by itself, we find it hitched to everything else in the universe."

Perhaps no problem exemplifies Muir's adage better than what we have come to call "global change." The intricate web of biological, chemical, geologic, anthropogenic, and other processes at work in the earth system cannot be understood by simple reference to one of its myriad component elements. Forecasts of future global change -- such as potential climate change, stratospheric ozone depletion, or changes in the chemical composition of the atmosphere -- necessarily involve an understanding of biogeochemical trends and equilibria, predictions about the enormously diverse socioeconomic activities that might perturb these equilibria, models of the likely resultant physical changes in the earth system, estimates of any eventual impacts on societies and ecosystems, and appreciation of interwoven feedbacks and synergisms.¹

Several different "radiatively active trace gases" (RATGs)² are emitted, removed, and influenced by human

¹ See, e.g., J. Smith and D. Tirpak, eds., The Potential Effects of Global Climate Change on the United States (1989), ch. 2.

² The term "radiatively active trace gases" (RATGs) refers to the group of substances that trap thermal radiation in the atmosphere, and that interact with other substances in the atmosphere to produce such gases indirectly or to prolong their atmospheric lifetimes. The related term "greenhouse gases" is also used.

activities. Because these gases are "radiatively active," their presence in the atmosphere may tend to raise the atmosphere's average temperature at the Earth's surface, and may thereby change the global climate. The greenhouse gases affected by human activities 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), volatile organic compounds (VOCs), and carbon monoxide (CO). Each greenhouse gas is emitted from a variety of sources and each has a different residence time in the atmosphere, a different ability to trap heat, and different potential impacts on the environment.

Policy formulations need to match the underlying ecological systems they address. The optimal design for the climate change convention, and for any policy responses, would be a "comprehensive" approach that addresses all relevant trace gases, their sources and sinks. This approach has been discussed by United States officials in several papers.³ The international perspective now seems to be broadening to match the ecological reality: integration of physical and social science is making clear that a comprehensive approach to the complex global system is essential, addressing all the relevant trace gases, their sources and sinks. In August the Intergovernmental Panel on Climate Change (IPCC) stated in its Overview: "A comprehensive strategy addresssing all aspects of the problem and reflecting environmental, economic and social costs and benefits is necessary."⁴ In November, the government ministers at the Second World Climate Conference (SWCC) declared: "We recommend that in the elaboration of response strategies, over time, all greenhouse gases, sources and sinks be considered in the most comprehensive manner possible..."⁵

In keeping with its commitment to a comprehensive approach, the United States has undertaken a set of policy

³ See U.S. "Concept Paper" submitted to the IPCC, 29 December 1989; U.S. Papers on "U.S. Experience with Comprehensive and Emissions Trading Approaches to Environmental Policy," Informal Seminar for IPCC WGIII officers, Washington, D.C., February 3, 1990; Richard B. Stewart and Jonathan B. Wiener, "A Comprehensive Approach to Climate Change," 1 American Enterprise 75 (November-December 1990); Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, pp. vii, 21-22.

⁴ IPCC Overview, August 1990, p. 14.

⁵ Ministerial Declaration of the SWCC, paragraph 14.

measures that together constitute a comprehensive approach, addressing several RATGs, sources and sinks, and will keep U.S. contributions to radiative forcing at 1987 levels through the year 2000. These actions are shown in Table 1 below. Several other nations have also endorsed or proposed following a comprehensive approach.⁶ Because each nation has a different economy, society, and portfolio of greenhouse gas sources and sinks, the best set of response measures will be different for each nation; a comprehensive approach provides flexibility for each nation to develop its most cost-effective mix of measures to fit its particular domestic needs while achieving global results.

If the international response to potential climate change is to be scientifically, environmentally and economically sound, it needs to take a comprehensive approach. Yet all too often, policy discussions zero in hastily on only one of many variables, in spite of our experience that narrow policies addressing only one attribute of a complex system typically provide little or no environmental benefit and incur significant cost. Where the understanding of the environmental system is highly incomplete, hasty adoption of policy measures may apply leverage to the wrong variables, missing or even exacerbating the true problem. In the current discussion, policy commentators initially gravitated to a narrow focus on one aspect of the issue: the potential global warming effects of carbon dioxide (CO₂) emissions from energy sector activities. This piecemeal approach ignores all the other aspects of climate change, including the several other RATGs, their diverse sources and sinks in all sectors of human activity, and their multiple environmental attributes. The result is a policy thrust that omits most of the science and neglects the foundations of effective policy.

The challenge to those who seek a sound approach to addressing potential climate change is to reorient the discussion to the environmental system and its comprehensive character.

⁶ See Canada's Green Plan (1990), pp. 97-108. Canada proposes actions on several RATGs in several sectors, and terms the strategy a "comprehensive response," *id.* p. 102. Other nations have announced proposals that address not only CO₂ but also other RATGs. See "Climate Change Policy in the Netherlands and Supporting Measures," Netherlands Ministry of Housing, Physical Planning and the Environment, D.G. for Environment, November 1990 (addressing CO₂ sources and sinks, CFCs, and CH₄); "Protecting the Earth's Atmosphere," Report of the Federal Cabinet Study Commission, Bonn, Germany, November 7, 1990 (addressing CO₂ and CH₄); "Action Program to Arrest Global Warming," Decision made by the Council of Ministers for Global Environmental Conservation, Government of Japan, October 23, 1990 (addressing CO₂ sources and sinks, CH₄, N₂O).

Table 1.A

**Emissions Reductions Expected in the Year 2000
Due to Current Environmental Commitments**

<u>Current Commitment (with RATG affected)</u>	<u>Millions of Tons of Carbon-Equivalents Reduced through 2000</u>
Tree Planting Initiative (CO ₂)	9
DOE Energy Efficiency Initiatives (CO ₂)	28
DOE Appliance Standards (CO ₂)	4
DOE Renewables Initiatives (CO ₂)	4
1990 Clean Air Act	
Acid deposition provision (CO ₂) ⁷	17
Other provisions (NO _x , CO, VOCs) ⁸	51
EPA Landfill Regulation (VOCs, CH ₄)	44
CFC Phaseout (CFCs) ⁹	551
<u>Total Reduction from 2000 Trend</u>	<u>657</u>

Source: Alex Cristofaro and Joel Scheraga, "Policy Implications of a Comprehensive Greenhouse Gas Budget," U.S. EPA, OPPE, draft September 1990, Table 2. Calculations use the IPCC 100-year radiative forcing ("GWP") index.

⁷ The 1990 Clean Air Act will achieve 16.4 million of the 17 million tons of CO₂ reduced through the incentives for energy conservation provided to electric utilities by the innovative emissions trading system the Administration created to reduce acid deposition precursors.

⁸ The Clean Air Act will also achieve reductions of 51 million tons of carbon equivalent reductions in NO_x, CO, and VOCs, especially through restrictions on mobile source emissions.

⁹ The figure includes only actions pursuant to the 1987 Montreal Protocol's 50% CFC phaseout; it does not take into account additional reductions the U.S. will achieve under the 1990 London update to a 100% phaseout.

Table 1.B

U.S. Emissions
(Million tons of carbon-equivalent)

<u>RATG</u>	<u>1987</u>	<u>2000, without Current Commitments</u>	<u>2000, with Current Commitments</u>
CO2	1310	1565	1503
CH4	234	252	208
VOCs	72	72	48
NOx	218	218	199
CO	52	52	45
N2O	74	74	74
CFCs	367	807	256
<u>Total:</u>	<u>2328</u>	<u>3040</u>	<u>2332</u>

Source: Alex Cristofaro and Joel Scheraga, "Policy Implications of a Comprehensive Greenhouse Gas Budget," U.S. EPA, OPPE, draft September 1990, Figures 4-5. Calculations use the IPCC 100-year radiative forcing ("GWP") index.

Chapter II: The Science of Climate Change

Several different "radiatively active trace gases" (RATGs)¹⁰ are emitted, removed, and influenced by human activities. Because these trace gases are "radiatively active," their presence in the atmosphere may tend to raise the atmosphere's average temperature at the Earth's surface, and may thereby change the global climate.¹¹ The RATGs affected by human activities 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), volatile organic compounds (VOCs), and carbon monoxide (CO).¹² Each RATG is emitted from a variety of sources and each has a different residence time in the atmosphere, a different ability to trap heat, and different potential impacts on the environment.

From the point of view of environmental quality, the focus of interest is the combined effect of all the RATGs. Assessing the combined effect of trace gases requires an understanding of their varied characteristics. RATGs 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, such as other effects on the environment

¹⁰The term "radiatively active trace gases" (RATGs) refers to substances that, when present in the atmosphere, act to trap thermal radiation; and to other substances that interact in the atmosphere to produce such greenhouse gases indirectly or to prolong their atmospheric lifetimes.

¹¹The term "potential global climate change" refers to possible changes in global and regional climate that may result from changes in the atmosphere's thermal radiation budget.

¹²Other 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. RATGs include aerosol particulates such as sulfur dioxide (SO₂), which can reflect insolation and thus may exert a net cooling influence. A fully comprehensive approach would encompass all such RATGs.

RATGs and radiative forcing

RATG molecules affect the radiative balance of the atmosphere, tending to trap heat and warm the Earth's surface. But RATGs do not all have the same impact on atmospheric warming: different molecules absorb thermal radiation at different efficiencies. That is, a molecule of CO₂ has a different potential for "radiative forcing" than a molecule of, say, N₂O. Estimates of this "instantaneous radiative forcing" impact are shown in the first column of Table 2. Estimating the instantaneous radiative forcing abilities of different trace gas molecules is generally a straightforward matter of laboratory research, and there is high confidence in these numbers. Certain complications arise due to the fact that the forcing effect is dependent on the ambient concentration: as the existing concentration of the gas in question rises, additional molecules add less and less to total radiative forcing. Thus, estimates of the instantaneous radiative forcing of a molecule (or kilogram) can be obtained given knowledge about the concentration of the gas; the estimates presented in the first column of Table 2 are for current concentrations. These estimates show that CO₂ is the weakest of the RATGs, unit-for-unit, at trapping thermal radiation at a given instant in time: CH₄ is 58 times more effective than CO₂, N₂O is about 200 times more effective, and CFC-11 and CFC-12 are from 4000 to 6000 times more effective.

The atmospheric residence time of RATGs also varies. Different trace gases remain in the atmosphere for different periods of time. Their "atmospheric lifetimes" or "residence times" depend on such variables as the rates at which they react with other gases in the atmosphere, and the rates at which they are removed by sinks. The prediction of the atmospheric lifetime of a trace gas is thus a mathematical function that depends, among other things, on the atmospheric concentration of relevant gases in the atmosphere, reaction rates in the atmosphere, and sink removal rates. The concentration of gases in the atmosphere depends, in turn, on such variables as the emissions rates, existing concentrations, reactions, and sink removal rates for those gases. Estimates of typical lifetimes, assuming current levels of relevant variables, are shown in the second column of Table 2. These estimates are subject to uncertainties, chiefly because the sink removal processes are not all well understood. For example, each CO₂ molecule cycles in and out of the atmosphere every 5-10 years, but is not finally removed from the atmosphere and deposited in the deep ocean for several hundred years; the "120 years" figure in Table 2 is a current best

estimate, but may change as the ocean-atmosphere carbon cycle is better understood.¹³

The reactivity of RATGs varies as well. Reactions are important sinks for RATGs, because as the molecules react they are broken apart and their atoms combined into new compounds. Some gases, such as N₂O, are fairly stable, and do not react much with other gases in the atmosphere. In contrast, CH₄, CO, VOCs, and HCFCs are all highly interactive. They often react with the hydroxyl (OH) radicals that abound in the lower atmosphere, indirectly affecting the abundance of other gases that would otherwise have reacted with the OH radicals. The presence of NO_x accelerates the formation of tropospheric ozone (O₃) from CO and VOCs; O₃ is itself a RATG. These kinds of "indirect" effects are included in the cumulative radiative forcing estimates shown in Table 2.

Scientists attempting to judge the cumulative radiative impact of each additional molecule added to the atmospheric concentration of a trace gas must take into account the instantaneous radiative forcing potential of the gas, its likely lifetime in the atmosphere, and its interactions with other gases. The calculation of the cumulative contribution to radiative forcing of each additional molecule over its lifetime can be complicated. Nevertheless recent attempts to calculate the different cumulative contributions of various RATGs, using the "global warming potential" (GWP) method of mathematically integrating the instantaneous radiative forcing of the gas over its probable lifetime, have reached fairly similar results.¹⁴ Table 2 presents the IPCC's estimates of relative radiative forcing per unit mass (kilogram) of each gas emitted, based on the GWP method.

¹³ The lifetime of gases also may have independent policy relevance because it affects the irreversibility of emissions, the ability to "back out" of unexpected difficulties. An erroneous underestimate of the severity of climate change may be harder to reverse if gases being emitted are long-lived than if they are short-lived.

¹⁴See, e.g., IPCC Scientific Assessment (1990), Chapter 2; Daniel Lashof and Dilip Ahuja, "Relative Global Warming Potentials of Greenhouse Gas Emissions," 344 *Nature* 529 (April 5, 1990); Thomas Levander, "The Importance of Greenhouse Gases other than Carbon Dioxide and Other Possible Differences Between Various Fuels," Swedish National Energy Administration (Heat & Electricity Production Div.) memorandum Sept. 14, 1989, presented to the OECD Group on Energy and Environment, Oct. 13, 1989.

Table 2

IPCC "Global Warming Potential" (GWP) Indices

<u>Gas</u>	Instantaneous radiative forcing per kg (rel. to CO2)	Atmospheric residence years (estimated)	Relative radiative forcing potential over years		
			<u>20</u>	<u>100</u>	<u>500</u>
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
HCFC-22	5440	15	4100	1500	510
HFC-134a	4130	16	3200	1200	420

(Source: IPCC Scientific Assessment, 1990, Tables 2.3, 2.8.)

Preliminary calculations with another method, employing large climate models to test the relative effect of a change in each gas on the realised temperature projected by the models, yield index values for other RATGs relative to CO₂, over a 100-year time horizon, that are roughly twice as large as the GWP method generates.¹⁵ In other words, this method shows CO₂ to be roughly half as important relative to the other RATGs as the IPCC GWP estimates (over 100 years). The differences between the climate model approach and the GWP calculation arise in part because the climate model approach calculated realised temperature change while the GWP calculated equilibrium temperature change, so the two measures may be useful for different purposes. Moreover, while the GWP method assumes possibly simplified dissipation functions and does not depict synergistic effects of multiple forcing agents, the climate models carry many other uncertainties (e.g. the crude or incomplete coupling or atmosphere, oceans, and land, or the limited ability to model cloudiness) that may affect their accuracy.

In any event, all of these studies make it clear that, even taking into account the potentially long atmospheric lifetime of CO₂ molecules, CO₂ has the least impact per unit on atmospheric radiative forcing: it is the weakest RATG. When one looks only at current human contributions to potential atmospheric warming, the effects of CO₂ appear to be large because the volume of CO₂ concentration and emissions is large compared to other anthropogenic trace gases. Assessments of the total contribution from each trace gas to changes in total atmospheric radiative forcing have estimated that CO₂ is responsible for roughly one half of current anthropogenic contributions, while other trace gases account for the remainder.¹⁶ But because the concentrations of most other trace gases are growing more rapidly than those of CO₂,¹⁷ and because of the relatively larger cumulative impact per molecule of other

¹⁵ T.M.L. Wigley, M.K. Hulme, and T. Holt, "An Alternative Approach to Calculating Global Warming Potentials," Climate Research Unit, University of East Anglia, Norwich UK (draft November 1990).

¹⁶ See IPCC Scientific Assessment (1990), Policy makers Summary, p. xx; U.S. Environmental Protection Agency, "The Potential Effects of Global Climate Change on the United States," Report to Congress, Dec. 1989, pp. 12-15 and Figure 2-4.

¹⁷ See U.S. Environmental Protection Agency, "The Potential Effects of Global Climate Change on the United States," Report to Congress, Dec. 1989, pp. 12-15 and Table 2-1.

trace gases relative to CO₂ (as described above), the relative contribution of CO₂ to total atmospheric radiative forcing has declined since 1880.¹⁸ Looking ahead, policy measures would have to address future increments of RATG emissions, so the environmental impact of each additional molecule is necessarily of primary concern.

Developing the radiative forcing indices

The time horizons used in the IPCC index -- 20, 100, and 500 years -- define the time over which one considers the impacts of radiative forcing. It is not clear which of these three time slices, or others, is appropriate for making decisions about potential climate change. Would the impacts of one unit of atmospheric warming be worse now, or in 2100, or in 2600? Given possible advances in technology and knowledge, and other potential changes in the environment, it is virtually impossible to predict what the impact of warming might be 500 years from now, and so one might decide to ignore radiative forcing effects beyond, say, 100 years. On the other hand, it is possible that distant future warming will burden an already increasingly stressed planet, and hence be more damaging. Put another way, what is the value to present persons of avoiding a unit of warming now, versus a unit of warming 100 years from now? At what rate might we "discount" future warming, as a proxy for discounting the future adverse impacts of warming? Adopting a shorter time horizon has the same effect as adopting a higher discount rate: future effects are deemed less worrisome than near-term effects. A simple linear extrapolation of the effects of warming over time is probably not exactly accurate,¹⁹ yet it is hard to tell today how else to estimate the importance of future radiative forcing. Every calculation of a radiative forcing index has used some form of weighting present and future effects.²⁰

¹⁸See U.S. Environmental Protection Agency, "The Potential Effects of Global Climate Change on the United States," Report to Congress, Dec. 1989, p. 15, Figure 2-4. Because of the imminent phaseout of CFCs, which represented 15-20% of radiative forcing in the 1980s, CO₂'s relative share of radiative forcing is predicted to be stable or increase in the future.

¹⁹ See Richard Eckaus, "Comparing the Effects of Greenhouse Gas Emissions on Global Warming," MIT Center for Energy Policy Research, November 1990.

²⁰ The IPCC uses time horizons. Lashof & Ahuja, supra use a discount rate.

Other improvements could be made in the radiative forcing index. Work is needed to harmonize various quantitative approaches and extend international understanding of indices, and to improve the accuracy 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 the National Oceanic & Atmospheric Administration (NOAA) laboratories is substantially improving estimates of the dissipation rate and residence time of CH₄ (which now appear to be longer than previously thought, thus raising the relative GWP of CH₄). As work on indices is ongoing, uncertainties in best estimates can be expressed and revised.

The indirect effects attributable to various gases' atmospheric reactions also need additional analysis. Certain trace gases react to form other radiatively important trace gases, or react with substances that would otherwise affect RATG abundances. These effects may be especially important for CH₄ and HCFCs. Another step to be taken is modeling index values as they are affected by "saturation" effects: as concentrations of gases grow, the band of the electromagnetic spectrum blocked by a gas may become occluded so that additional increments of the gas have diminishing marginal radiative forcing impacts. Current radiative forcing estimates could be revised to account for these diminishing potencies in future years with higher concentrations. And estimates need to take account of the implications that vertical and other distribution of RATGs in the atmosphere may have for calculated index values. Most generally, institutional mechanisms for developing a consensus index and adjusting it to new research results need to be developed. The framework convention could spur the formation or nomination of such institutions.

Although these uncertainties remain in the GWP values, the consensus of the IPCC was that the scientific method of calculating GWPs is sufficiently sound to permit its use. Similarly, an international workshop on GWP Indices organized by NOAA, EPA, NASA, UKDOE and others in Boulder, Colorado in November 1990, concluded that though these uncertainties require urgent attention, they do not undermine the scientific fundamentals of the GWP index and do not warrant abandoning it. For practical policy purposes, some weighting system is unavoidable: not using an explicit index means weighting other gases at zero, or haphazardly. A fairly good index, appropriately employed, is a great deal better than no index at all. A good but imperfect index could serve well and then be amended later when knowledge improves.

More complete indices: toward a "global change index"

RATGs also have other environmental impacts, but these characteristics are not accounted for in the radiative forcing index. Radiative forcing is only an intermediate physical effect of trace gases, and is really a proxy used as a common metric to compare the diverse RATGs.²¹ But RATGs have multiple attributes of societal and ecological concern; 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, NOx, 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,²² increasing crop yields and improving their drought-resistance.

Accurate understanding of the environment that will prevail in a world of higher RATG concentrations, as well as the optimal design of incentives for policy choices, would entail developing a comparative index that incorporates the full externalities (social and ecological costs) imposed by increments of each RATG.²³ And it might try to take account of the variations in the cost of warming incurred at different times and different places.²⁴ Without a more "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 economists' words, significant externalities will remain uninternalized, and the incentive signals of the narrow index may produce perverse

²¹Measurement 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 generally incorporated into the radiative forcing index because such impacts stem from warming generically, and are not expected to vary depending on the type of gas enhancing the warming.

²² See Norman Rosenberg, et al., "From Climate and CO₂ Enrichment to Evapotranspiration," in Paul Waggoner, ed., Climate Change and U.S. Water Resources (1990), pp. 151-75.

²³ See John Reilly, "Climate Change Damage and the Trace Gas Index Issue," USDA, Economic Research Service, draft November 1, 1990.

²⁴ See Richard Eckaus, "Comparing the Effects of Greenhouse Gas Emissions on Global Warming," MIT Center for Energy Policy Research, November 1990.

outcomes. Efforts to limit warming that totally ignored other consequences might generate unacceptable increases in ozone depletion or toxic air pollutants, or deprive crops of needed atmospheric carbon.

For example, if only CO₂ concentrations double over the next several decades, climate-induced crop yield losses may be largely offset by the positive yield effects due to CO₂'s "fertilization" and water use efficiency effects on plants. If equivalent RATG doubling were, however, due completely to gases other than CO₂, then these positive offsets would not be realized. And if the RATG increase were made up of gases with other harmful effects, such as CFCs or very large quantities of CFC substitutes that still deplete the ozone layer, there would be additional negative consequences besides warming. The upshot is that society should be interested in focusing any control efforts where they will do the most good, considering all environmental impacts.

Crafting a "complete" index of ultimate costs poses quite difficult analytic and technical problems. Data are not yet 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. Predicting economic effects far into the future is, as noted earlier, a highly inexact science.

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 RATGs, such as the direct effects of CO₂ enrichment and the ozone depletion impacts associated with CFCs and other halocarbons.²⁵ The diverse global impacts of the gases would be estimated using best economic forecasting tools, coupled with expert evaluations of the ecological impacts and of the relative importance of the diverse impacts. This "global change index" would thus be an improved, albeit still incomplete, proxy for ultimate economic and ecological damages. It would capture the main global externalities associated with the gases, providing significantly better policy signals than an index limited to radiative forcing. It would nonetheless require effort and time to construct; the global change index should therefore be developed as a complement to and in tandem with the more technically manageable radiative forcing index.

²⁵ Essentially local attributes of the gases, such as their toxicity, would be left to local policy strategies.

A very preliminary estimate has been made of a somewhat more complete index of global environmental impacts. By incorporating the incremental impact of RATGs due to only two effects -- radiative forcing and CO2 enrichment of agriculture -- one study has estimated the following index values:

Table 3

Comparisons of Trace Gas Indices

<u>RATG</u>	Physical Effects: Instantaneous <u>Radiative Forcing</u>	Economic Impacts: Climate Effects <u>+ CO2 Fertilization</u>
CO2	1	1
CH4	58	92
N2O	206	260
CFC-11	3970	6343
CFC-12	5750	9119

Source: From John Reilly, "Climate Change Damage and the Trace Gas Index Issue," USDA, Economic Research Service, draft November 1, 1990, Table 3.

The "instantaneous radiative forcing" index values in column 1 are simply taken from the IPCC, as shown above in Table 2. The estimates in column 2 of the economic effects of climate change -- due to radiative forcing and CO2 fertilization of crops -- are derived by computing the effects of radiative forcing in climate forecasting models, and using estimates of future economic and environmental impacts under different climate and CO2 regimes to estimate net economic impacts. Both the climatological and the economic forecasting models are subject to significant uncertainties, so the economic impacts index shown above is necessarily uncertain. In addition, the index computed here only accounts for the economic impacts of warming and CO2 fertilization on global agriculture, omitting effects on other sectors and on ecosystems.²⁶

Nevertheless, the index in Table 3 suggests the great importance of the non-warming impacts of the RATGs. It suggests that a unit of social resources expended to limit emissions of CH4 generates about 90 times more benefit than the same unit of

²⁶ In addition, Reilly's economic effects index does not account for the depletion of stratospheric ozone due to CFCs, which would markedly increase CFCs' index values (assuming ozone depletion is highly damaging to humans and the environment). Nor does it account for the local toxicity of certain RATGs.

resources spent to limit CO₂ -- rather than roughly 60 when considering only radiative forcing. It thus suggests that counting radiative forcing alone leads to a substantial underestimate (by about a third) of the value of controlling CH₄ relative to CO₂, and likewise a substantial overstatement of the value of controlling CO₂ relative to CH₄. Similar comparisons may be made for the other trace gases. And because the index shown in Table 3 does not account for the ozone-depleting effects of CFCs, a more complete index incorporating those serious environmental impacts would raise the CFC figures further, probably well above the 6300 and 9000 figures shown here; in other words, the relative benefit of controlling CFCs is still understated in this index.

Policy implications of RATG science

These scientific observations lead to the conclusion that any sound effort to address potential global climate change must address all relevant trace gases, and treat them in accordance with their different environmental impacts. Considering both radiative forcing potential, of which CO₂ is the least potent anthropogenic agent, and the non-warming impacts of the RATGs, it is clear that unit-for-unit, CO₂ is the most environmentally benign of the RATGs. If society and the biosphere had to accept any given amount of predicted warming, then on purely environmental grounds (abstracting from the costs of limitation strategies), it would prefer to have as much of that given amount of warming due to CO₂ and as little due to other RATGs.

At the same time, the lifetime of gases has independent policy relevance because it affects the irreversibility of emissions, that is, the ability to "back out" of unexpected difficulties. An erroneous underestimate of the severity of climate change is harder to reverse if gases being emitted are long-lived than if they are short-lived.²⁷ Thus, while the residence time is already incorporated in measures such as the GWP index, it has additional importance where the ultimate impact of radiative forcing is highly uncertain.

Whether the goal is to understand, predict, or limit potential atmospheric warming, attention must be paid to all the gases contributing to that result. Predicting radiative forcing without good data on the RATGs other than CO₂ would clearly be unsatisfactory, as elaborated in Chapter IV. An understanding of the relative contributions of different trace gases to potential

²⁷ On the other hand, if for some reason it later turns out that warming is desirable but difficult to generate quickly, it might be better to have emitted more long-lived RATGs.

atmospheric warming (and other environmental impacts) is a prerequisite for setting a research agenda and for assessing the costs and benefits of different policy responses. Placing limits on emissions of just one gas would leave other gases unrestricted; this problem is discussed further in Chapter V. And limiting emissions of certain gases may be less costly to society (or to different nations or sectors of society), or more beneficial to the environment, than limiting others; this topic is taken up in Chapter VI.

Diverse sources and sinks

Similarly, the scientific nature of how RATGs enter and leave the atmosphere indicates that attention should be paid to the full range of their sources and sinks. Trace gases are generated by numerous sources, including human ("anthropogenic") activities, other biological activities, and non-biological processes. Among the anthropogenic sources of trace gases are virtually every sector of human activity, including mining, energy generation, transportation, agriculture, forestry, waste disposal, industry, building and residential services, and others. Biogenic sources are similarly diverse. The full range of sources deserves attention in developing effective response strategies.

Meanwhile, some gases are removed from the atmosphere by "sinks" such as trees, phytoplankton, ocean mixing, and chemical reactions. Whether the goal is to predict or limit emissions of RATGs, contraction and expansion of sinks is an important component. Sink conservation and expansion might achieve net emissions limits at potentially lower cost per molecule than restrictions on some sources of trace gases. Moreover, expanding sinks such as forests can have other important environmental and economic benefits, such as protection of biodiversity and soil conservation. If response strategies are to address the possible causal factors of potential global climate change, the variety of both sources and sinks of trace gases must be included.

Examples of the sources and sinks of each of several RATGs are presented in Table 4. Other sources and sinks not affected by human activity have been omitted from the Table, such as photochemical destruction of N₂O in the upper atmosphere. The enormously diverse set of sources and sinks shows the pervasive and complex web of human activities that affect RATG concentrations. This is both an opportunity and a challenge: an opportunity to understand the full set of human interactions that may contribute to climate change, and a challenge to avoid focusing narrowly on one source or sink while ignoring others. As Chapter V explains in greater detail, the interconnected web of human activities worldwide that affect RATG emissions makes

narrow policies inappropriate: narrow regulations are likely to be undermined as economic actors shift away from regulated sources toward unregulated ones.

For certain of the sources and sinks listed in Table 4, data and models are not yet sufficient to quantify their contributions to net emissions. As Chapter IV describes, a critical goal of the framework convention and other efforts should be to improve understanding and measurement of these sources and sinks.

Table 4
Selected Sources & Sinks Subject to Human Influence

<u>Gas</u>	<u>Sources</u>	<u>Sinks</u>
Carbon dioxide (CO ₂)	Fossil fuel combustion Land clearing Biomass combustion	Forests Grasses Soils Ocean biota & storage
Methane (CH ₄)	Livestock: enteric fermentation, wastes 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 Biomass combustion	Soil removal
Halocarbons (CFCs and related)	Refrigerants Aerosol propellants Foam blowing agents Solvents and cleaning agents Fire retardants	Recapturing and destroying existing supplies
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 Industrial processes	Atmospheric OH interaction
Aerosols/sulfates (e.g. SO ₂)	Fossil fuel combustion	

Chapter III: Defining a Comprehensive Approach

A. Description of the 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), their sources and sinks. RATGs include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halocarbons such as chloro-fluorocarbons (CFCs) and related substances (HCFCs, HFCs), and tropospheric ozone (O₃), whose precursors include oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and carbon monoxide (CO).²⁸ Different RATGs arise from different sources²⁹ and are removed from the atmosphere by different sinks,³⁰ yielding a "net emissions" budget.

Different RATGs have different impacts on the environment; for example, each gas has a different ability to alter the earth's heat balance by trapping certain radiated energy (or reflecting it). This influence on the earth's thermal balance, referred to as "radiative forcing," is described in Chapter III. In order to relate the comparative environmental impacts of the various RATGs, the comprehensive approach employs a parameter or "index" that calculates the relative environmental impact of each gas. One basis for such an index is the

²⁸Other RATGs affect the radiative balance of the atmosphere, but their main influence is not through absorption of energy reradiated from the Earth's surface; these include aerosol particulates such as sulfur dioxide (SO₂), which can reflect insolation and thus may exert a net cooling influence.

²⁹For purposes of predicting trace gas concentrations and lifetimes, "sources" includes all anthropogenic, biogenic and other sources of RATGs emitted into the atmosphere. When calculating nations' RATG net emissions inventories and the effects of policy actions, the sources of concern are those influenced by human activity.

³⁰For purposes of predicting RATG concentrations and lifetimes, "sinks" includes all anthropogenic, biogenic, atmospheric and other activities, processes, and phenomena that remove greenhouse gases from the atmosphere or reduce their atmospheric lifetimes. Examples of sinks include soils and trees, oceanic phytoplankton, ocean mixing, and atmospheric chemical reactions. When calculating nations' RATG net emissions inventories and the effects of policy actions, the sinks of concern are those influenced by human activity.

contribution of increments of each gas to physical effects, such as radiative forcing, used as proxies for global environmental impacts. 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.

RATGS also emanate from diverse sources and are removed from the atmosphere by diverse sinks (see Table 4). Because the focus of environmental inquiry is the change in atmospheric concentrations of the gases, not source emissions per se, the comprehensive approach encompasses all of these sources and sinks in the concept of "net emissions."

B. Policy context

The comprehensive concept is an "approach" or heuristic that offers insight into any discussion of response strategies for potential climate change. It addresses the "how to" question -- how to design any policy (including research, technology development, and other options) that might be adopted to respond to potential climate change. Its principal aim is to improve the framework of research and analysis, and the cost-effectiveness of any choice, by encompassing all the important variables and guiding investments of time and effort to those that are most important. It does not directly address the larger cost-benefit question of "how much" investment of time and effort should be made -- what level of social investment, if any, is warranted by risks of potential climate change. By shedding light on the full costs and benefits of alternative proposals, it does help to answer the "how much" question.

C. Multiple applications.

The utility of a comprehensive approach is not limited to the design of emissions limitation policies. Whether the strategy is pursuing scientific research, promoting new technology, evaluating policy proposals, identifying measures warranted on other grounds that also have potential climate benefits, or designing actual emissions limitations policies (whether domestic or international), a comprehensive approach suggests the desirable breadth, emphasis and direction of the strategy. It provides the guide to maximize the environmental benefit of any expenditure of social resources.

As a means of defining the agenda for science and economics research (such as research on the likelihood or impacts of potential climate change, or on the means, costs and benefits of response options), the comprehensive approach ensures that all RATGs, sources and sinks are considered, and that environmental impacts (including radiative forcing and other effects) are

considered. It also suggests the key areas for improved measurement of sources and sinks of RATGs. And it provides a guide to the benefit that will be obtained from improved knowledge of each variable in the human-climate system. 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. This suggestion is illustrated in Chapter IV.

As an approach to technology development, a comprehensive approach assists in identifying and comparing the relative importance of technologies and practices affecting potential climate outcomes. For example, if nations are to develop or transfer technology under a climate convention, or to provide financial assistance, a comprehensive approach could be used to assess the impact of each project on potential climate change. How would a new facility, or a new method of crop cultivation, affect net RATG emissions? How can ozone-depleting substances be replaced without generating other RATGs? The comprehensive approach provides the tools to answer such questions.

As a means of evaluating current policies or proposed policies, a comprehensive approach provides a metric for identifying and assessing the impacts of policy actions in the climate context. It could form the basis for calculating the aggregate impact of various measures on a nation's net RATG emissions. What would be the climate impact of a new energy tax, revised forestry policies, or a change in agricultural subsidies? Using a comprehensive approach would provide the basis for the proper consideration of any policy options.

As an approach to possible emissions limitation rules or obligations (whether domestic or international), a comprehensive approach provides an environmentally coherent and least-cost design for limitations policy. It provides the proper signals to guide responses to maximize environmental benefit. It also avoids the dangers of a piecemeal approach, focused on one gas (e.g. CO₂) or one sector (e.g. energy), which would omit salient RATGs, sources and sinks and hence could induce unintended shifts of economic activities from the narrowly regulated aspect to unregulated modes that effectively offset or even increase emissions of RATGs. This danger is evident from experience in more traditional contexts, where, for example, focusing on air emissions alone has led to shifts of pollutants from air to toxic solid sludge discharges. In the climate context, 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 facility leaks.

The comprehensive approach cures these environmental 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. A comprehensive approach could be applied to a variety of emissions limitation measures, including emissions taxes and emissions trading, and including both domestic and international measures. If applied internationally, it has the additional benefit of reserving to each nation the flexibility and autonomy to decide its mix of domestic policies regarding the array of gases, sources and sinks that that nation determines would best accomplish policy goals in light of that nation's unique social, economic, cultural and institutional circumstances.

The comprehensive approach would also employ performance-based incentives rather than the "command-and-control" design standards that have historically been used in environmental policy, requiring those who emit a substance to apply specific technological controls such as "best available control technology." That approach is insensitive to the variation in costs and options faced by diverse emitters; environmental protection could be achieved at less cost if limitations were obtained using the least-cost option in each place. It discourages innovation in control technologies, and efficient use of resources, because the mandated "best" technology is "locked in," with no reward for innovations or reduced consumption of resources. An incentive-based approach would encourage diverse, innovative, cost-effective responses.

D. Experience with the Comprehensive Approach.

1. Stratospheric ozone depletion: the Montreal Protocol. A recent example of a "comprehensive" approach adopted by the international community to address atmospheric environmental policy is the method employed in the Montreal Protocol on Substances that Deplete the Ozone Layer. Indeed, the description above of a comprehensive approach for trace gases bears resemblance to the approach taken in the Montreal Protocol for ozone depleting substances. Parties to the Montreal Protocol are obligated to limit and then reduce their production (and their imports, exports and consumption) of two Groups of substances listed in Annex A.³¹ Each substance in Annex A is assigned an "Ozone Depleting Potential" value, calculated to

³¹Annex A may be amended in the future to list additional substances that deplete stratospheric ozone.

represent the average cumulative contribution of an additional increment of the substance to ozone depletion. Rather than requiring each nation to achieve specific percentage reductions in each ozone depleting substance, the Protocol requires an overall percentage reduction in the total production of each of the two Groups. Under Article 3, "production" of each Group to be restricted is calculated by multiplying annual production of each substance by its Ozone Depleting Potential, and then adding together the resulting figures.³² Consumption, imports and exports are limited according to the same approach.

The comprehensive approach employed in the Montreal Protocol is likely to prove advantageous in several respects. First, environmental quality -- in this case, protection of the stratospheric ozone layer -- will be furthered. Each nation will meet its obligation to restrict total production from each Group of substances. If the Montreal Protocol had restricted production of only one substance, economic activity could have adjusted to reduce output of that substance while increasing the output of other ozone depleting substances. In contrast, the approach taken in the Montreal Protocol improves the chances that the most important ozone depleting substances will be restricted, and that activities will not shift to producing other substances that pose as large a threat to the ozone layer.

Second, the comprehensive approach preserves flexibility for nations to design their own best means of compliance. In a piecemeal approach, specific limitations would be required for each substance. Each nation would find some of those limitations extremely costly, but others so inexpensive that further reductions (though not required) would not have been burdensome. Under the Montreal Protocol, however, these inefficiencies are, in principle, largely avoided by permitting each nation to choose within each Group which substances to restrict, so long as the overall weighted production limits are met. Different nations can choose different mixes that take account of the varying Ozone Depleting Potential of each substance and of the varying socioeconomic value of each substance to different societies. For example, a nation whose economy depends heavily on one CFC can reduce those emissions more slowly but take extra steps to reduce its use of another CFC, so long as the overall reduction in weighted production fulfills its obligations. Each nation can thus choose the cost-

³²The Montreal Protocol also allows for limited transfer of this calculated level of production among parties, for the purpose of industrial rationalization. See Article 1, paragraph 8, and Article 2, paragraph 5.

minimizing mix of restrictions to achieve its combined limit of the weighted production amounts of each substance.³³

Similarly, the Montreal Protocol prudently employs performance-based limits. In contrast to an approach imposing "design standards" or other rules requiring use of specific technologies, the performance-based approach used in the Montreal Protocol requires those who emit a substance to limit emissions, and leaves to the emitter the choice of what methods, technological or otherwise, to employ. As compared to design standards, performance-based limits encourage lower-cost responses by emitters, more innovations in control techniques, and more efficient resource uses, to the benefit of society, while achieving the emissions limit desired.

The concept of "net emissions" described above is not pertinent in the context of the Montreal Protocol because significant human-influenced "sinks" do not exist for the CFCs and halons regulated in Annex A.

2. Multimedia policy. Restrictions on emissions that apply narrowly to one kind of source of a pollutant can result in compliance strategies that, while adhering to the law, fail to reduce environmental degradation. Regulations on one environmental "medium," such as air quality, can induce shifts in pollution to another medium, such as land or water disposal. Recognizing the inherent and recurring problems in a single medium approach, the U.S. is now developing and implementing a more comprehensive, integrated strategy to address the "cross-media" difficulties of our initial system of environmental control. It is examining strategies for "pollution prevention" that address the multiple pollutants that may enter the several environmental media, and that attempt to reduce risk by reducing the total generation of pollution rather than focusing only on the "end of the pipe." It is bringing enforcement actions that simultaneously charge violations under several laws, in order to achieve a multimedia solution to an area's environmental problems. For example, the United States recently brought enforcement actions against several facilities in Northwest Indiana, along the Grand Calumet River, charging violations of the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act (the law governing hazardous waste management), and the Safe Drinking Water Act. By bringing simultaneous

³³The United States, for example, is implementing its obligations under the Montreal Protocol through domestic use of a "comprehensive" approach: U.S. industry must limit its total production, weighted by the Ozone Depleting Potential index. This permits industry to devise the best mix of reductions in regulated substances, encouraging least-cost, innovative responses.

actions against several neighboring facilities and for multimedia discharges under several statutes, the United States is seeking to ensure that the pollutants addressed by one statute are not simply converted into a different form of pollution, and that pollution control at one facility is not offset by increases at another; the goal is to promote the overall environmental quality of the area by dealing with all environmental impacts in a comprehensive fashion.

3. "Bubbles." The use of "bubbles" for air quality protection is a program that bears similarity to the "comprehensive" approach, and it is a program with which the United States has extensive, positive experience. Under the Clean Air Act, each region of the United States must attain ambient air quality standards. Existing, modified, and new sources of emissions are all regulated to achieve the ambient standards; depending on the type of source and whether the area is "in attainment" or not, sources must employ a range of emissions controls. As part of its efforts to implement the ambient air quality requirements and the emissions control requirements, the U.S. Environmental Protection Agency (EPA) designed the "bubble" program. The word "bubble" is used because the design suggests an imaginary bubble covering a plant with multiple emissions sources. Under the "bubble" program and related rules, in attainment areas, the EPA allows existing industrial and utility plants with emissions emanating from multiple sites to reallocate emissions among the sites within the plant or set of plants, so long as total emissions do not increase. Thus, if a plant has several smokestacks, it can rearrange the emissions released from each smokestack so long as the total emissions from all its smokestacks does not increase. States that are delegated authority to implement the Clean Air Act's requirements have also designed "bubble" programs that they allow industrial emitters to adopt.

The "bubble" is a good example of a comprehensive approach to environmental protection that has been in place for several years (since 1979) and that has proved successful. The fundamental principle of the bubble, like that of the comprehensive approach described here for trace gases, is the same: actors should retain the flexibility to rearrange their emissions so long as their total quantity of emissions achieves the aggregate goal.³⁴

³⁴Because the Clean Air Act regulates individual pollutants, each "bubble" is applied to emissions of a single pollutant, and in that respect the "bubbles" differ from the comprehensive approach suggested for application to the multiple array of greenhouse gases. But the bubble approach derives from the same policy rationale that supports the comprehensive approach:

(continued...)

United States experience with the "bubble" has been extensive and promising. There were 132 approved bubble reallocations in the U.S. between 1979 and 1985. The bubble program has resulted in significant cost savings to society: over these 132 bubble reallocations, savings amounted to over \$430 million, for an average of over \$3 million per use of the bubble program. And these cost savings were obtained even with the potentially expensive requirement that emitters must receive approval for the bubble reallocation from the state and, if the state has not been delegated authority to implement the program, from the regional and national EPA as well.

Moreover, the significant savings under the bubble program have been achieved without any increase in total emissions. In fact, some early evidence indicates that the bubble program has induced net reductions in total emissions.

4. Administration proposal to limit acid precipitation. The Administration proposed, but Congress did not enact, a provision for multipollutant trades as part of legislation to reduce emissions of air pollutants that contribute to acid precipitation. Because acid precipitation is believed to be the result of both SOx and NOx emissions, the Administration proposal regulated both substances and allowed trading between the two. Emitters would have been required to reduce SOx and NOx emissions, but each emitter could have varied its own mix of SOx and NOx reductions, so long as the overall target was attained. The gases were weighted in the proposal so that an extra pound of emissions of SOx above the limit must be matched by more than a pound of reduction in NOx emissions.

5. Canadian NOx-VOCs Management Plan. As part of its recent "Green Plan," the Canadian government has proposed a program to reduce urban smog by limiting emissions of NOx and VOCs. Canada proposes to allow trading between sources and between NOx and VOCs emissions, using a ratio of the gases' impacts on smog production to calibrate the trades, and requiring that aggregate emissions do not exceed government-issued allowances.³⁵

6. Agricultural toxics. Recognizing that "it is not just one pesticide that is the source of ... contamination," one commentator has suggested using a comprehensive approach to regulation of the numerous pesticides that are applied to

³⁴(...continued)
promoting least-cost approaches to effective environmental protection.

³⁵ Canada's Green Plan, 1990, pp. 53-55.

farmers' fields. Using an index to relate the comparative impacts of the different chemicals on the environment, the approach would leave to farmers the choice of which chemicals to apply -- so long as the aggregate index-weighted set of chemicals did not exceed the regulated limit. This approach would allow diverse farmers the flexibility to employ different pesticides in different circumstances, while protecting environmental quality by reducing overall contamination effectively. Without such a comprehensive approach, an inflexible requirement of identical reductions by all would deny farmers in different settings, or growing different crops, the opportunity to vary their mix of protective substances; and limits on one pesticide might induce increased use of another, more harmful substance.³⁶

³⁶ See Susan Capalbo and Tim Phipps, "Designing in Environmental Quality: Possibilities in U.S. Agriculture," Conference paper presented at American Enterprise Institute, Washington D.C., June 11-12, 1990, pp. 23-24.

Chapter IV:
A Comprehensive Approach to Research and Monitoring

A. Measuring and Monitoring Atmospheric Concentrations

Any environmental impacts resulting from RATGs would be associated with changes in the actual concentrations of RATGs in the atmosphere, not with emissions per se. The comprehensive approach ensures that data are gathered on atmospheric concentrations of all relevant trace gases. 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 trace gases will remain an essential function under a comprehensive approach.

Clearly, exclusive attention to CO₂ concentrations, disregarding other RATG concentrations, would not make scientific sense. No professional atmospheric scientist would limit his or her attention to CO₂ alone, for even at their current small concentrations, the effect of the other RATGs on additional (human-induced) radiative forcing are believed to be equal in magnitude to the effects of CO₂. A comprehensive approach to research and monitoring of atmospheric concentrations, addressing all the RATGs, is clearly warranted. The framework convention should include steps to fill the gaps in our understanding of RATG concentrations, atmospheric processes and dynamics. For example, the convention could:

- o Establish or enhance a global concentration monitoring network for the relevant trace gases. Ensure appropriate geographic coverage to measure gradients and distributions. Develop techniques, methodologies and standards for monitoring, and disseminate this information. Nations would agree to undertake monitoring and share methods and data. The network would build on the many existing systems, such as the WMO Global Atmosphere Watch, rather than create new institutions.
- o Organize data collection centers and structures to receive, code, interpret and report on data collected by the network. Charge the IPCC to coordinate and assess this work.

B. Measuring and Monitoring Net 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 are 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. First, such data are needed to establish current baseline net emissions of RATGs, in order to validate current model estimates and resolve uncertainties in the calculations of national and sectoral net emissions. These data will serve to improve estimates of current net emissions, for aggregate and national or sectoral predictions.

Second, these data will be essential to resolving uncertainties in the calculation of comparative gas indices, which depend on estimates of the typical residence times of gas molecules, and thus in turn on information about source-sink balances.

Third, these data will be critical to projecting future net emissions. Predictions of future net emissions trends are a key input into global climate models used to predict atmospheric warming. A piecemeal approach, focusing on CO₂, could seriously undermine the accuracy of estimates of the real rate and extent of future climate change. A comprehensive approach to net emissions of all RATGs, however, would ensure more accurate and reliable forecasts of future net emissions, and hence of future concentrations.

The measurement of net emissions faces many obstacles and uncertainties, and the framework convention could address these data gaps. Many current studies confine themselves to CO₂ and energy policy alone simply for the reason that, in the words of one analyst, "[t]his focus suggests itself because the necessary quantitative data for a least-cost analysis are far more developed in the case of energy than for other major sources

of greenhouse gases."³⁷ Unless research is carried out along a comprehensive approach, a narrow and incomplete knowledge base will yield surprises for policy makers, and incomplete and flawed piecemeal policy responses.

In order to improve net emissions monitoring, the Convention should set goals and priorities for research and monitoring following a comprehensive approach. The IPCC or another appropriate body could be tasked to coordinate and assess this work. The convention could advance efforts along the following lines:

- o Organize efforts to harmonize current emissions monitoring methodologies, techniques and systems.

For example, the convention could assemble multinational programs to compare and harmonize the methods used to monitor CH₄ emissions from fossil fuel mines and transmission systems, from livestock, or from rice fields; N₂O emissions from soil biota under different agricultural practices; and so forth.

To take a recent example: there is some controversy over the proper way to monitor emissions from forestry. At the macro level, there is debate over the techniques for interpreting satellite data in estimating forest cover. At the micro level, there are differences of view over the effectiveness of different tree types, tree ages, and forestry practices (through their effects on trees, soil biota, and moisture) at fixing atmospheric carbon.

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

- o Identify and calculate accurate proxies or surrogates to estimate net emissions factors from hard-to-measure activities, such as diffuse sources and sinks in agriculture and forestry. Even today, energy CO₂ emissions are not measured directly by smokestack monitoring devices, but are calculated from data on the carbon content of fuels and the efficiency of the combustion process. Similarly, CH₄ emissions factors for livestock could be tested under diverse conditions and diets, and calculated by applying the emissions factor to the number of cattle (perhaps counted by satellite sampling and ground observation).
- o Sponsor workshops or research programs on atmospheric chemical reactions of relevant trace gases. For example,

³⁷ F. Krause, et al., Energy Policy in the Greenhouse, (IPSEP / European Environmental Bureau / Dutch Ministry of Housing, Physical Planning and Environment, September 1989), Volume One, p. I.1-3.

host a Workshop on Methane Interactions, or a Workshop on HCFC Interactions. The output from the Workshops would help describe how concentrations change (through better knowledge of residence times and dynamics), 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. Interactions with hydroxyl (OH) radicals in the lower atmosphere are of special interest and in need of study; OH interactions affect (or are affected by) numerous RATGs, including CH₄, NO_x, CO, O₃, and VOCs, yet information is needed about trends in the ambient abundance of OH, specific reaction dynamics, and synergistic effects when multiple RATGs are present.

- o Organize a thorough study of the carbon cycle (atmosphere-ocean-terrestrial sinks). This could build, for example, on the U.S. CEES effort to understand all carbon processes. This work would generate critical information about, among other important topics, CO₂ residence time. CO₂ residence time is 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 radiative forcing index values relative to CO₂.
- o Create micro-monitoring field programs, to match the concentration monitoring programs described above by measuring actual emissions and uptake from surface activities. For example, better understanding of the biological, chemical, and physical processes involved in the emissions and deposition of N₂O, CH₄, and NO_x is needed. 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. The effort would make sure to include coverage of both industrialized and developing country emissions. Clinical and field studies of the key processes involved would also be undertaken. 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 (see bullet 2 above).

- o Develop national inventories. Efforts are already underway to assemble inventories of net emissions of RATGs for many nations, including OECD and U.S. EPA's analysis of CO₂, CH₄, CFCs, HCFCs, N₂O, CO, NO_x, and NMHCs for the US and other nations. The convention could build outward from these projects to calculate baseline net emissions inventories for all nations. It could invite all nations to regional workshops, and feed the data into centers where these data can be used in emissions forecasting efforts.
- o Develop comprehensive economic models. To forecast future emissions and the effects of policy proposals, new and expanded economic models are needed that cover multiple trace gases, multiple sectors, sinks as well as sources, better detail on developing countries, international trade effects, and so forth. An economics research program could pursue this effort.
- o Organize a program to develop monitoring technology, including remote sensing (satellite observation using lasers, etc.), aerial reconnaissance, on-site instruments, flux measurement techniques, etc. For example, it could create a Tropospheric Ozone Monitoring Technology Clearinghouse. It could encourage development of devices that can be operated in the field at modest skill levels. The program could award recognition, funding, and/or possible forms of international intellectual property rights to scientists, engineers, and others who invent useful devices.

The convention could also address, or task the IPCC to assess, options for institutional arrangements to improve monitoring. These options include arrangements for monitoring and reporting and their relation to sovereignty concerns, e.g. voluntary or mandatory national reporting; remote sensing; atmospheric observations; international oversight bodies; permission for on-site field studies; incentives and institutional designs to encourage development and application of accurate monitoring & reporting, for example by assuring credit for net RATG limitation actions upon a showing by the emitter of successful monitoring practices; international expert panels; international research centers; cooperative monitoring projects.

These options are meant to illustrate the range of research and monitoring topics embraced and spurred by a comprehensive approach. Certainly other research efforts, such as into the role of clouds and oceans, would be needed to develop a complete understanding of the climate system. Yet without attention to a comprehensive approach, even a full understanding of the ocean-atmosphere system would lack crucial knowledge of the human-influenced inputs to potential climate change.

Chapter V: Environmental Advantages of a Comprehensive Approach

A. The Pitfalls of Piecemeal Approaches

A comprehensive approach to environmental policy, and to issues of climate change in particular, is highly desirable because its alternative -- a piecemeal approach that focuses on one gas and sector -- is environmentally flawed. If the goal is sound environmental protection, a piecemeal approach is unlikely to succeed and could backfire.

Piecemeal policies are typically beset by a notorious drawback: "shifts" or "displacements" of pollution as activities move away from the regulated area to unregulated but still deleterious forms. Piecemeal policies place a regulatory or financial burden on certain targeted activities, such as emissions sources of a certain pollutant. Rational, law-abiding businesses and individuals react to that burden by finding other legal ways of running their operations -- new emissions controls, new fuels, new product materials, new process designs, new products, new plant locations, new emissions outlets -- that avoid the burden. But the new operations typically produce other types of "residuals" -- emissions or wastes that injure the environment -- thus undermining, counteracting, or even reversing the protective effect of the piecemeal policy. By squeezing on only one end of the socioeconomic balloon, piecemeal policies simply make the balloon bulge out at another end.

This problem is especially acute in the climate context, where the several trace gases are emitted by virtually every sector and type of human activity, from energy to industry to agriculture, on every part of the planet. The social and economic activities that produce these trace gases, from fuel combustion to traditional agriculture, are intricately interrelated and widespread. Policies that restrict emissions of one trace gas from one source, such CO₂ from energy production, are bound to induce shifts to activities that yield emissions of other gases, or in other sectors, not targeted by the piecemeal policy. These shifts would seriously impair the environmental effectiveness of the piecemeal policy, and could even mean net increases in contributions to radiative forcing.

1. Past Experience with Piecemeal Policies

Historically, piecemeal policies have often proved environmentally ineffective or even counterproductive. The history of environmental policy has been piecemeal; command and control efforts have in almost every country been aimed separately at the three main environmental "media": air, water, and land. This has often led to "cross-media shifts" in

residuals, moving pollution around without reducing it.³⁸ Past experience in the United States, for example, demonstrates the reality and the likelihood of such shifts. The major U.S. environmental laws, such as the Clean Air Act, the Clean Water Act, and the hazardous waste statutes, were each written to address one environmental medium. Breaking pollution control down into these piecemeal categories may initially seem logical, but we have learned through frustrating experience that shifts from one environmental medium to another have thwarted attempts to reduce pollution.³⁹ One commentator has aptly observed: "In attempting to help Eastern Europe, the Soviet Union, and the Third World with air pollution problems, western industrial countries should not simply transfer wholesale the [end-of-pipe] pollution control strategies that have not been entirely successful at home. An ill-conceived approach such as this could do more harm than good. ... A comprehensive approach will be necessary that focuses on pollution prevention rather than pollution control."⁴⁰

For example, stringent regulations on water pollution have induced industry to convert liquid pollutants into sludge, in turn creating toxic waste disposal problems. Similarly, to reduce air pollution, standards were written to require installation of "scrubber" technology to remove sulphur dioxide (SO₂) emissions from electric utility smokestacks. Yet these rules have resulted in increased generation of solid wastes.⁴¹ Another unanticipated dysfunction of the scrubber requirement is that while it removes SO₂, attaching the scrubber impairs the operating efficiency of the utility boiler, so that more fuel is needed to produce the same amount of energy. In consequence, SO₂

³⁸ See U.S. EPA, Science Advisory Board, "Reducing Risk: Setting Priorities and Strategies for Environmental Protection," SAB-EC-90-021 (September 1990), Recommendation 7, p. 22, and Strategic Options Report, section 4.3.

³⁹ See Office of Technology Assessment, From Pollution to Prevention 1987; Daniel J. Dudek, "Lessons from U.S. Experiments in Environmental Reform," Environmental Defense Fund, presented at the international workshop on Institutional Design for Environmental Protection in Poland, September 17-20, 1990, at 9.

⁴⁰ Hilary F. French, "Clearing the Air," in Worldwatch Institute, State of the World 1990 at 118.

⁴¹ See Dudek, "Lessons," supra note 1; Hilary F. French, "Clearing the Air," in Worldwatch Institute, State of the World 1990 at 111.

emissions were reduced but other pollutants generated by fuel combustion -- such as CO₂ -- were increased.⁴²

Restrictions on emissions that apply narrowly to one kind of source of a pollutant can also result in compliance strategies that, while adhering to the law, fail to reduce environmental degradation. For example, laws regulating smokestack air pollution were written to require that the ambient air quality in the locality of the smokestack not fall below certain levels. One industry response to this approach was to build taller smokestacks, so that the pollutant plumes were fed into higher wind currents and were dispersed more rapidly from the local area. Although pollutants were removed from local areas, they often continued to degrade the environment farther downwind. The result was that, although no law was violated, overall pollution was reduced much less than the law had contemplated. Although spreading these pollutants downwind did dilute their concentrations and thus reduce threats to human and ecological health, the strategy of building tall smokestacks meant that the environmental benefits were much less than hoped. And populations downwind received unexpected pollutant loadings. Later, the laws were amended to try to prevent such outcomes.

Recognizing the inherent and recurring problems in a piecemeal approach to pollution, the U.S. is now developing and implementing a more comprehensive, integrated strategy to address the "cross-media" and "cross-source" difficulties of our system of environmental control. It is examining strategies for "pollution prevention" that address the multiple pollutants that may enter the several environmental media, and attempt to reduce risk by reducing the total generation of pollution rather than focussing on the "end of the pipe."⁴³ It is bringing enforcement actions that simultaneously charge violations under several laws, in order to achieve a multimedia solution to an area's environmental problems. For example, the United States recently brought enforcement actions against several facilities in Northwest Indiana, along the Grand Calumet River, charging violations of the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act (the law governing hazardous waste management), and the Safe Drinking Water Act.

⁴² See Daniel J. Dudek, Alice M. LeBlanc, and Peter Miller, "SO₂ and CO₂: Consistent Policymaking in a Greenhouse," Environmental Defense Fund, New York, January 1990.

⁴³ See U.S. EPA, Science Advisory Board, "Reducing Risk: Setting Priorities and Strategies for Environmental Protection," SAB-EC-90-021 (September 1990), Recommendation 7, p. 22, and Strategic Options Report, section 4.3.

By designing policy and enforcement to address simultaneously several pollutants at several facilities under several statutes, the United States is seeking to ensure that the pollutants targeted by one statute are not simply converted into a different form of pollution, and that pollution control at one facility is not offset by increases at another. The goal is to reduce overall pollutant emissions as pollution is prevented, and to enhance the overall environmental quality of the nation. Dealing with all environmental impacts in a comprehensive fashion will substantially improve the ability to reduce deleterious pollution while heading off compliance strategies that merely shift pollution around.

Along these lines, one of the best examples of a global environmental policy -- the Montreal Protocol -- was itself designed in a comprehensive way that reduced the potential for cross-pollutant shifts. If the Protocol had restricted production of only one substance, such as the most prevalent CFC, economic activity might have adjusted to reduce output of that substance while increasing the output of other ozone depleting substances. In contrast, the multi-substance approach taken in the Montreal Protocol, using the Ozone Depleting Potential (ODP) index to weight the substances, greatly improves the chances that the most important ozone depleting substances will be restricted, and ensures that activities will not shift to producing other substances that pose as large a threat to the ozone layer.⁴⁴

2. Shifts in the Climate Context

Unwanted shifts of emissions to unregulated activities are likely to plague piecemeal policies in the climate context as well. Rational actors reacting to piecemeal policies are likely to pursue unregulated means to their goals, potentially inadvertently continuing to contribute to radiative forcing. The dominant tenor of current policy discussion on climate has

⁴⁴ At the same time, the ODP values do not account for the global warming potential of the CFCs or their substitutes. See Donald A. Fisher, et al., "Model Calculations of the Relative Effects of CFCs and their Replacements on Stratospheric Ozone," 344 Nature 508 (April 5, 1990); and Fisher, et al., "Model Calculations of the Relative Effects of CFCs and Their Replacements on Global Warming," 344 Nature 523 (April 5, 1990). In this sense the Montreal Protocol is piecemeal, addressed only at the stratospheric ozone depletion problem, and in compliance with the Protocol economic activity may shift to CFC-substitutes that have lower ODPs but have significant GWPs. A more comprehensive approach that accounts for all of the CFCs' and CFC-substitutes' atmospheric impacts, including both ozone depletion and climate change, would address this problem.

focused piecemeal on one narrow aspect: CO2 emissions from the energy and transport sectors. Yet that focus, or any other piecemeal focus in the climate context, is likely to yield dysfunctional shifts in emissions. Precisely because the human activities that produce radiatively active trace gases are so widespread, varied, and currently ingrained in both industrialized and developing societies, shifts are especially likely to occur in the climate context.

(a) Fuel switching, CO2 and CH4. A salient example of a plausible cross-gas shift is the case of "fuel switching." Under a piecemeal CO2-only limitations policy, utilities and businesses would likely be encouraged to switch from coal or oil to natural gas, because with current combustion techniques coal burning produces almost twice as much CO2 per BTU as burning natural gas, and oil burning produces about 50% more.⁴⁵ Several studies show that imposition of a constraint on CO2 emissions would lead to considerable fuel-switching from coal and oil toward natural gas,⁴⁶ because fuel switching is estimated to be one of the most cost-effective means utilities have to reduce their CO2 emissions.⁴⁷ Several national plans have proposed

⁴⁵ See Rodhe, "A Comparison of the Contribution of Various Gases to the Greenhouse Effect," 248 Science, 8 June 1990, p. 1218.

⁴⁶ See, e.g., Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, pp. 26, 29; Manne & Richels, "CO2 Emission Limits: An Economic Analysis for the USA," paper presented at the Workshop on Energy and Environmental Modeling and Policy Analysis, MIT Center for Energy Policy Research (July-Aug. 1989); U.S. Congressional Budget Office, "Carbon Charges as a Response to Global Warming: the Effects of Taxing Fossil Fuels," August 1990, pp. 27-30, 44; Commission of the European Communities, DG XII, JOULE Program, "CO2 Study: Crash Programme: Cost-Effectiveness Analysis of CO2 Reduction Options, 'Bottoms-Up' Approach," Parts I and II (working draft Oct. 1990).

⁴⁷ See Daniel J. Dudek and Alice LeBlanc, "Offsetting New CO2 Emissions: A Rational First Greenhouse Policy Step," 8 Contemporary Policy Issues 29 (July 1990), pp. 38-39, Table 4; Commission of the European Communities, DG XII, JOULE Program, "CO2 Study: Crash Programme: Cost-Effectiveness Analysis of CO2 Reduction Options, 'Bottoms-Up' Approach," Parts I and II (working draft Oct. 1990).

switching to natural gas as key parts of their domestic policies to limit CO₂ emissions.⁴⁸

But use of natural gas means methane (CH₄) leakage from natural gas mining and transmission systems (pipelines and local distribution networks). Because CH₄ is itself the product being transported and sold, where energy markets are competitive there is a market incentive to capture fugitive CH₄ emissions. But where markets are less competitive or where the cost of capture exceeds the revenue to be gained from the leaking CH₄, leaks go uncorrected. Today CH₄ leaks from natural gas transmission average about 2-4% worldwide.⁴⁹ For example, the average is probably about 1% in the U.S.,⁵⁰ it is 3% in Australia,⁵¹ and is probably in the range of 5-10% in the Soviet Union and Eastern Europe.⁵²

Switching from coal to natural gas would be encouraged by a CO₂-only policy, but might not reduce, or could even increase, contributions to radiative forcing. One recent study⁵³ estimates that a 6% rate of CH₄ leakage from natural gas

⁴⁸ See, e.g., "Climate Change Policy in the Netherlands and Supporting Measures," Netherlands Ministry of Housing, Physical Planning and the Environment, D.G. for Environment, November 1990, § 3.2.1., p. 6; "Protecting the Earth's Atmosphere," Report of the Federal Cabinet Study Commission, Bonn, Germany, November 7, 1990.

⁴⁹ See IPCC Response Strategies Working Group, "Methane Emissions and Opportunities for Control," coordinated by Japan Environment Agency and U.S. EPA (September 1990), p. 34.

⁵⁰ Communication from John Hoffman, U.S. EPA, Office of Air & Radiation.

⁵¹ See Jim Falk & Andrew Brownlow, The Greenhouse Challenge (Penguin Books Australia, 1989), p. 270, citing Walker, I.J., and Lydall, K.D., "The Potential for Reduced CO₂ Emissions through Increased Energy Efficiency and the Use of Renewable Energy Technologies in Australia," Commonwealth Dept. of Primary Industries and Energy, Canberra (1989), p. 13.

⁵² Communication to U.S. EPA, Office of Air & Radiation, Office of Atmospheric & Indoor Air Programs, Global Change Division, from OEKO-Institute Bro Darmstadt, FRG, based on study by A.A. Arbatov, Deputy Chairman, USSR Academy of Sciences Commission for the Study of Production Forces and Natural Resources.

⁵³ Rodhe, "A Comparison of the Contribution of Various Gases to the Greenhouse Effect," 248 Science, 8 June 1990, p. 1217.

transport would completely negate all of the CO₂-related radiative forcing avoided by switching from coal to natural gas (and a 4% leakage rate would completely negate all of the CO₂-related radiative forcing avoided by switching from oil to natural gas).⁵⁴ Thus, at today's world average CH₄ leakage rates, the reduced CO₂-related radiative forcing achieved by coal-to-gas fuel switching would be offset about 50% by CH₄ leaks. In other words, if implemented through coal-to-gas fuel switching, a policy to reduce CO₂ emissions by, say, 20% would actually achieve only a 10% reduction in CO₂-equivalent contributions. That would be a major failure of the CO₂ limitations policy. And in the Soviet Union and Eastern Europe, currently major coal consumers with access to large supplies of natural gas, the CO₂-related reductions from coal-to-gas switching would be offset more than 100% -- that is, net contributions to radiative forcing would actually increase in response to the CO₂-only emissions policy.

If implemented through oil-to-gas fuel switching, the reduced CO₂-related radiative forcing induced by the CO₂-only policy would be offset even more, by about 100% worldwide -- that is, the CO₂-only policy would have no effect whatsoever on aggregate radiative forcing, with the likelihood of quite significant net increases in radiative forcing when applied in Eastern Europe.

The comprehensive approach, on the other hand, would account for CH₄ emissions and thereby ensure that methane leakage is included in a nation's net trace gas emissions inventory and in the incentives and efforts to limit net emissions. Indeed, in some nations the capture of CH₄ leaks might be a highly cost-effective strategy for limiting contributions to radiative forcing. But a CO₂-only policy would ignore that option and discourage it, in effect encouraging CH₄ leaks.

(b) Non-energy shifts. Shifts among trace gases are possible in the agriculture and forestry sectors as well. Some proposals to reduce methane emissions from wet rice cultivation involve increased application of nitrogenous fertilizers, which yield nitrous oxide emissions.⁵⁵ Certain proposals to reduce methane emissions from livestock also depend on increased use of

⁵⁴ Rodhe's calculations do not account for CH₄ leaks from coal mining, so these leakage rates would need to be slightly higher to offset all the radiative forcing avoided by reducing coal consumption.

⁵⁵ EPA, Policy Options for Stabilizing Global Climate (Draft August 1990), pp. V-157, V-161, V-163.

feed grains grown with nitrogenous fertilizers.⁵⁶ Given that the radiative forcing potential of nitrous oxide over a mid-range period (100 years) is over 10 times larger than that of methane,⁵⁷ small tradeoffs could be significant enough to offset or outweigh the savings in methane-equivalent emissions. Similar risks are present in the forestry sector, where calls to increase the productivity of trees as CO2 sinks might be pursued by applying nitrogenous fertilizers.

(c) Shifts across sectors. Shifts could occur across sectors as well. If a CO2-only policy induced the substitution of ethanol (made from corn) for carbon-containing petroleum gasoline, CO2 emissions would decline, assuming the corn farm did not displace CO2 sinks. But corn cultivation is one of the most fertilizer-intensive of crops,⁵⁸ and nitrous oxide emanating from the application of nitrogen fertilizers to corn fields is roughly 200 times more potent a RATG than CO2.⁵⁹ Similarly, a policy aimed at the transport sector alone could encourage the use of electric vehicles (EVs), which themselves emit no CO2. But the full emissions of the EVs depend on what source of energy charges their batteries: if the charging came from coal-fired power plants (whose emissions are not counted in the "transport-only" policy), the net contribution to CO2 emissions and to radiative forcing could actually increase.⁶⁰ To take another example, policies to stop deforestation and thereby preserve CO2 sinks could inadvertently increase CO2 emissions, because communities that now burn harvested wood for fuel may turn to coal for their energy.

These shifts may not be inevitable; technologies and practices could perhaps be chosen that take account of all relevant trace gas emissions. But without the system-wide outlook and the incentives provided by a comprehensive approach, the choice of optimal technologies is extremely unlikely. Under

⁵⁶ EPA, Policy Options for Stabilizing Global Climate (Draft August 1990), p. V-166.

⁵⁷ IPCC Scientific Assessment (1990), Table 2.8.

⁵⁸ EPA, Policy Options for Stabilizing Global Climate (Draft August 1990), p. V-160.

⁵⁹ IPCC Scientific Assessment (1990), Table 2.8.

⁶⁰ This observation is buttressed by data in a recent study and a seminar presentation by its authors. See Hadi Dowlatabadi, Alan Krupnick, and Armistead Russell, "Electric Vehicles and the Environment: Consequences for Emissions and Air Quality in Los Angeles," Resources for the Future, Draft 1990.

piecemeal proposals, there is no reason to think that an overall optimal emissions outcome would emerge, and there is every reason to think that narrow efforts will yield narrow results. Piecemeal policies to limit air, water and land pollution have regularly produced inadvertent shifts of emissions. The much more numerous and interrelated socioeconomic systems and practices that generate net emissions of the several trace gases provide a much more complex catacomb of unseen passageways for such shifts to occur. In the climate context perhaps more than in traditional environmental areas, piecemeal policies seem to be a recipe for dysfunction and disappointment.

3. Piecemeal coverage of emitters

A different kind of inadvertent shift is the result of policies that address only a subgroup of emitters. If the environmental problem were pollution of a lake, it would make little sense to restrict pollutant discharges from one beach on the lake, but leave sources of pollution around the rest of the lake unregulated; polluting industry on the regulated beach could comply with the law by moving around the lake, or by extending discharge pipes around the lake to emit pollutants in the unregulated zone. Similarly, if one is worried about regional air pollution, it makes little sense to forbid emissions in one local area while leaving neighboring areas unrestricted; industry will move to the unregulated area and continue emitting. These are examples of a general flaw in policies that apply piecemeal to subgroups of sources emitting pollutants that mix in the shared environment: if the scope of policy coverage fails to encompass all the emitters, emissions will shift to the unregulated areas and the environment will not be much improved.

In the climate context, such shifts would be likely to attend restrictions on trace gas emissions applied piecemeal to one nation or group of nations. Because the trace gases relevant to climate change mix globally in the atmosphere and their effects would be global, emissions at any location are equally important to the global ecosystem. Limits on emissions by one subgroup of emitters must be evaluated in terms of their influence on overall global emissions.

Take for example the proposal for only a few nations to restrict their CO₂ emissions, or the view that climate change could be adequately addressed by CO₂ emissions limits imposed solely in the industrialized nations of the OECD. These proposals are inadequate for several reasons. First, any trace gas limits would need to be global because the emissions of the industrialized nations make up a rapidly declining share of global emissions:

Growth Rates of CO2 Emissions⁶¹

<u>Time Period</u>	<u>U.S.</u>	<u>OECD</u>	<u>Non-OECD</u>
1966-1976	2.40	3.51	5.22
1976-1986	-0.47	0.58	2.43

If the developing nations continue on current trends, absent steps to avoid land use practices and energy production methods that emit substantial amounts of trace gases, by 2030 they will account for roughly half of global CO2 emissions. Even at today's shares, a 20% reduction in current CO2 emissions by the OECD alone would remove only 3% of current global human contributions to radiative forcing. (CO2 from fossil fuels make up 34-37% of global contributions to the enhanced greenhouse effect in the 1980s (with deforestation accounting for 22-26%, CFCs 20%, and other gases 20-21%),⁶² so a 20% reduction in global CO2 would be about a 7% reduction in global radiative forcing; and OECD nations now account for 43% of fossil fuel CO2 emissions,⁶³ so a 20% reduction in their CO2 emissions would reduce global CO2 by about 3%.) OECD-only policies simply could not achieve a global 20% reduction in CO2 emissions -- to say nothing of RATG emissions generally -- without action by the developing nations as well. Without developing country reductions, the OECD would have to eliminate more than 100% of its CO2 emissions to reduce global emissions by 20%.⁶⁴

⁶¹ Calculated from Gregg Marland, "Estimates of CO2 Emissions from Fossil Fuel Burning and Cement Manufacturing Based on U.N. Energy Statistics and U.S. Bureau of Mines Cement Manufacturing Data," Oak Ridge National Laboratory, ORNL/CDIAC-25, NDP-030 (1989). If these data included CO2 emissions from land clearing, the growth rates in the Non-OECD would be even higher.

⁶² R.A. Houghton, "The Global Effects of Tropical Deforestation," 24 Env't Science & Technology (1990) p. 414.

⁶³ Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, p. 18, Table III.1.

⁶⁴ Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, pp. 19-21, Tables III.2 & III.3.

Second, the effectiveness of an OECD-only reduction policy would be limited by the possibility of shifts in emissions to other nations where no restrictions apply, offsetting or even increasing in emissions worldwide. As the nations who decided to reduce CO2 emissions (the "signatories" to a limitations agreement) restricted their consumption of fossil fuels, world prices of those fuels would fall. The reduced prices would lead to increased consumption in other nations where limits on CO2 emissions were not in place ("non-signatories"). The increased consumption could partially or even totally offset the reduced CO2 emissions achieved by the signatories.⁶⁵ In addition, if the change in the world fuel price led to more consumption by the non-signatories than the initial reduction by the signatories (i.e. if the price elasticity of demand of the non-signatory economies were high), net fossil fuel consumption could actually increase as a result of the signatories' action. And net CO2 emissions would be given additional upward pressure if the amount of CO2 emitted per unit of fuel consumed were higher in the non-signatory economies than in the signatory economies.

Third, over the slightly longer term, restrictions by the subgroup of emitters would be offset as products made with high-emitting technologies were increasingly manufactured in the non-signatory areas and imported back into the signatories, and as high-emitting industries moved out of the signatory states to unregulated locations in the non-signatory states.

Fourth, as described earlier in this Chapter, limits on CO2 alone would not effectively address overall contributions to radiative forcing. A comprehensive approach to all RATGs is warranted.

Comprehensive scope of coverage and wide global participation in any trace gas limitations measures would therefore be essential. As the IPCC noted, "Climate change is a global issue; effective responses would require global cooperation."⁶⁶

⁶⁵ See Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, p. 27; Peter Bohm, "Mitigating Effects on Fuel Prices from Incomplete International Cooperation to Reduce CO2 Emissions," (draft December 1990).

⁶⁶ IPCC RSWG Policymakers' Summary p. ii.

B. Optimal Environmental Signals

A comprehensive approach to research and policy provides optimal environmental signals to guide choices. While a piecemeal approach would ignore and omit important RATGs, sources and sinks, a comprehensive approach would make clear the relative environmental significance of each factor, and encourage decisionmakers to design responses -- whether they be research strategies, technology choices, or emissions limitation incentives -- that generate optimal environmental results.

In order to provide a sound guide to policy choices, a measure of the relative environmental impacts of the gases, an "index" as described in Chapter II above, should be used to set priorities. Rather than taking piecemeal stabs in what might be called the proverbial "radiative darkness," good policy choices demand elucidation of the relative effects of the various emissions. And it must be recognized that some weighting of the gases is unavoidable: a piecemeal policy targeting CO₂ alone effectively weights the other gases at zero.

The comprehensive approach provides the signals that enable the environmental benefit of any response measures to be maximized. Such environmental signals are needed if real environmental benefit is to be achieved. Otherwise, priorities will be set haphazardly, rather than in furtherance of ecological well-being.

Aiming at one RATG alone, for example, would omit other gases with potentially greater adverse impact on the ecological system. Take the case of CO₂-only policies: CO₂ is, molecule for molecule, the least potent radiative forcing agent of the major anthropogenic trace gases. Because any limitation policies must necessarily address future increments of net emissions, it is the comparative impact of additional amounts of each gas that must be addressed. Meanwhile, CO₂ may provide significant environmental benefits that the other trace gases do not: CO₂ is the grist of photosynthesis, and can improve plants' water use efficiency as well. The other trace gases confer no such benefits, and some pose serious threats beyond radiative forcing; CFCs deplete the stratospheric ozone layer, while other RATGS are toxic. In sum, if one is really interested in promoting global environmental welfare, and if global warming is really a threat warranting preventive action, then policies aimed at restricting CO₂ alone would not be ideal, and could be counterproductive: CO₂ is in a sense the most benign of the RATGs, and for any given level of warming that might occur, one would probably prefer (assuming for the moment equal costs of abatement across gases) to have as much of that given warming due to emissions of low-forcing, plant-

enriching CO₂ as possible, and less due to the other RATGs according to their relative environmental impacts.

Beyond the case of CO₂-only emissions limitations, the comprehensive approach continues to offer the guidance for optimal decisions to maximize environmental benefits per unit of social resources expended. How is a project manager to choose between two agricultural techniques, one which emits methane and the other nitrous oxide? How is a nation to make the same kind of choice? The comprehensive approach provides the signals to yield optimal environmental outcomes to these choices.

The use of performance-based incentives under a comprehensive approach would also improve the environmental performance of any response measures. Historically, command-and-control regulations have required those who emit a substance to apply specific technological controls, such as "best available control technology." That approach discourages innovation in control technologies, because the mandated "best" technology is "locked in" and innovations are not rewarded. And it discourages improvements in raw materials choices and resource use efficiency that would limit the total amount emitted, because it gives businesses no incentive to conserve fuels or otherwise minimize emissions once the control technology is in place.⁶⁷ Hence technology standards dampen the innovation and resource use efficiency that is critical to promoting environmental quality over the longer term. The comprehensive approach, by employing a performance-based incentive that leaves the choice of the means to comply to the individual emitter, encourages least-cost, innovative, and resource-efficient responses.

C. Net emissions: enhancing sinks

The comprehensive approach gives sinks the serious attention they deserve. For RATGs, it is net emissions that would be of ecological concern, the result of both emissions from sources and removal by sinks, including trees, grasses, soil biota, oceanic phytoplankton that fix atmospheric carbon, and crops.

By addressing "net emissions," the comprehensive approach would thus give incentives for sink conservation and enhancement. Preserving and properly managing forests and other vegetation, or protecting carbon-fixing phytoplankton from

⁶⁷ That is why, as described in Chapter IV, mandating scrubbers to remove SO₂ resulted in increased CO₂ emissions. See Daniel J. Dudek, Alice M. LeBlanc, and Peter Miller, "SO₂ and CO₂: Consistent Policymaking in a Greenhouse," Environmental Defense Fund, New York, January 1990.

anthropogenic injury such as from toxic waste disposal at sea, could help sequester carbon released from surface sources. These sink-enhancement actions could carry with them significant side-benefits in biodiversity, oceanic food webs, reduced soil erosion, and better timber management. At the same time, management of sinks is a complex endeavor, and poorly designed sink enhancement policies could have adverse impacts on sink ecosystems.

Chapter VI: Economic and Institutional Flexibility

A. Economic flexibility.

If emissions limits are warranted, the comprehensive approach allows each emitter to use that combination of source and sink controls and other measures that is best suited to its economic and other circumstances, achieving environmental protection at significantly lower cost than a gas-by-gas strategy. This approach maximizes the opportunity for and encourages the adoption of diverse, flexible, innovative, and cost-effective solutions to global climate change.

Some have proposed dictating specific percentage emissions reductions for each RATG, and applying those limits uniformly to every nation. It has been suggested that every nation should reduce CO₂ by 20%, CH₄ by 10%, and so on. Yet mandating specific limits on each gas would be significantly more costly than limits designed according to a comprehensive approach, in which an overall limit would apply to each nation's aggregate contribution of net RATG emissions, weighted by an appropriate index. Both approaches would limit net emissions, but the comprehensive approach would permit each nation to adopt its best, least-cost mix of choices for achieving the overall limit.

1. The prevalence of cost variations.

The costs of RATG abatement are certain to vary considerably across countries and across gases, sources and sinks. The variation of costs across gases, sources and sinks, and nations means that what is a least-cost policy for one nation will almost certainly not be the least-cost policy for another. Under the comprehensive approach, each nation would have the autonomy and flexibility to design its own least-cost mix of policies addressing the various RATGs, sources and sinks. Under a piecemeal or gas-by-gas approach, nations would be bound to adhere to the uniform reduction goals set by the international negotiations; this centralized control of response options would clearly impose extreme costs on certain nations, and would unnecessarily raise overall costs worldwide.

Allowing each nation the flexibility to design its least-cost policy response mix will reduce global costs of any response. Some nations might find it inexpensive to reduce CO₂ emissions significantly, but be unable to reduce CH₄ output (e.g., a nation importing oil and dependent on rice crops, but endowed with untapped solar power opportunities). Those nations would prefer to meet any net emissions limits by reducing CO₂ more rapidly than CH₄; requiring them to limit each gas by a set amount would prove much more costly (perhaps in terms of lower

economic growth, higher taxes, or reduced rice production) and would leave additional affordable CO₂ reductions unexploited. Other nations might find themselves in the opposite situation, able to afford to limit CH₄ more than CO₂ (e.g., a nation dependent on coal reserves but able to modify the diet of its ruminant animal husbandry).⁶⁸

Including sinks in the calculation of "net emissions" will also offer desirable economic flexibility to nations who are able to comply with trace gas limits more cost-effectively by restoring and promoting sink expansion than by restricting sources. For example, a nation might find it less costly to remove a quantity of trace gases from the atmosphere by planting trees than to prevent emissions of the same quantity of gases from industrial sources. Moreover, sink development could yield additional economic advantages, including reducing soil erosion from agricultural lands; improving timber supply management; enhancing tropical forest biodiversity, which may contribute to useful products such as medicines; and protecting fish harvests by limiting pollution of waters that serve as phytoplankton habitats.

These points are intuitively obvious, because each nation has a different inventory of sources, sinks, and RATG emissions, as shown in Table 5, and hence a different set of RATG emissions reduction options. It makes no sense for a central body to dictate to each nation what that nation's response must be, when the same environmental result could be achieved by that nation at much less cost through a different set of responses.

⁶⁸ A similar analysis applies to approaches mandating specific changes in sources alone or sinks alone, rather than combining them in a "net emissions" requirement that leaves the domestic policy mix to each nation.

Table 5.A

(insert EPA/OECD emissions inventory spreadsheet)

Table 5.B

(insert EPA US-UK-India pie charts)

The fact that nations' net emissions inventories are different under a comprehensive (all RATG) approach than under a CO2-only approach, it should be noted, does not mean that some nations "win" or "lose" under a comprehensive "ranking" system. "Ranking" is not the point; the point is reducing the marginal cost of RATG abatement. The total size of a nation's emissions does not determine the nation's cost of abatement. For example, Nation A might have small CO2 emissions and large CH4 emissions, so it would "rank" lower on a CO2-only approach. But it would nevertheless benefit from a comprehensive approach, because of the flexibility offered by the comprehensive approach in selecting least-cost response options. Indeed, the cost of abatement in Nation A might well be lower for CH4 than for CO2 -- that is, the marginal cost of reducing its large CH4 emissions might be less than the marginal cost of reducing its CO2 emissions -- in which case it would clearly be better off under a comprehensive approach even though its "ranking" could be higher. The key issue for cost-minimization is the marginal cost of abatement, not total emissions, and a comprehensive approach is very likely to offer reduced marginal cost of abatement to all nations -- every nation "wins."⁶⁹

It is also increasingly clear as an empirical, quantitative matter that the cost of abatement varies significantly across gases and nations. First, recent analyses confirm that costs of abatement vary widely across RATGs. Analysis of additional steps the U.S. might take to limit net RATG emissions in 2000 shows that planting an additional billion trees per year (doubling the billion per year to be planted under the President's Tree Planting Initiative) would cost almost \$100 per ton of carbon-equivalent avoided, while imposing tighter landfill restrictions could reduce VOCs and CH4 at a cost of only about \$11 per ton of carbon-equivalent avoided. These figures are shown in Table 7 below. Nobel Laureate William Nordhaus has estimated that in the U.S., the cost of phasing out CFCs is about \$5 per ton of carbon-equivalent avoided, while options for reducing CO2 emissions begin at about \$10 per ton and quickly rise to hundreds of dollars per ton.⁷⁰

⁶⁹ A nation whose emissions inventory grew enormously under a comprehensive approach might be somewhat worse off. If Nation B had zero CO2 emissions and truly gigantic CH4 emissions, it might prefer to be governed under a CO2-only approach. But under a CO2-only approach, the significant environmental impact of Nation B's CH4 emissions would be ignored -- not a result that serves the global interest.

⁷⁰ See William Nordhaus, "Economic Policy in the Face of Global Warming," Yale University, draft March 9, 1990.

These are simply illustrative examples; these cost figures would not apply in all nations, at all times, or in all regions of the U.S. They make clear, however, that the costs of RATG abatement vary quite widely from gas to gas.

Table 6

Costs Vary Across RATGs

<u>Project</u>	<u>RATG units avoided (million tons of carbon-equivalent)</u>	<u>Annual Costs (millions)</u>	<u>Cost per RATG unit avoided</u>
Tighter EPA Landfill Restrictions (VOCs, CH ₄)	39	\$431	\$11
Planting 1 Billion More Trees Yearly (CO ₂)	9	\$850	\$95

Source: Alex Cristofaro and Joel Scheraga, "Policy Implications of a Comprehensive Greenhouse Gas Budget," U.S. EPA, OPPE, draft September 1990, Table 7. Calculations use the IPCC 100-year radiative forcing ("GWP") index.

Second, costs vary considerably even among different types of projects to restrict emissions of one gas. Economists at Environmental Defense Fund have estimated the costs of CO₂ avoidance through various measures, and have found a wide range of costs per ton avoided, as shown in Table 7. Similarly, the U.S. Forest Service has estimated that the cost of sequestering CO₂ in U.S. trees varies from \$5.26 to \$43.33 per ton of carbon.⁷¹

⁷¹ Robert Moulton and Kenneth Richards, "Costs of Sequestering Carbon Through Tree Planting and Forest Management in the United States," U.S. Department of Agriculture, Forest Service, GTR WO-58 (December 1990).

Table 7

Costs Vary Across Sources and Sinks

<u>Option</u>	<u>Cost per Ton CO2 Avoided</u>
Trees with Conservation Reserve Program (CRP) Contribution	\$3.48-\$5.49
Trees Without CRP Contribution	\$6.64-\$10.67
Biomass Plantation	\$8.16
CO2 Scrubbing and Disposal	\$59.41
Shade Trees	\$1.35-\$6.74
Conservation	\$5.73
Fuel switching (oil to gas)	\$4.48

(Source: Daniel J. Dudek and Alice LeBlanc, "Offsetting New CO2 Emissions: A Rational First Greenhouse Policy Step," 8 Contemporary Policy Issues 29 (July 1990), Table 4.)

Third, costs can also vary for different levels of investment in a single project, as opportunities to restrict the source or expand the sink become more scarce. That is, there are typically rising marginal costs to expanding RATG avoidance efforts. For example, EPA estimates that sequestering 9 million tons of carbon in trees in the U.S. in the year 2000 would cost about \$545 million, but sequestering an additional 9 million tons of carbon in U.S. trees would cost about \$850 million -- about 75% more -- for a total of \$1.4 billion per 18 million tons sequestered. And repeating that effort, i.e. sequestering another 18 million tons for a total of 36 million tons, would cost another \$2.3 billion -- about 165% more.⁷²

These kinds of cost variations, all estimated for the U.S. economy, would undoubtedly occur across nations as well. The great differences in circumstances of different economies -- variations in energy, industrial, transportation, agricultural and forestry systems, in consumption patterns, in capital formation, in labor force characteristics, in land availability, in population density, and so forth -- almost guarantee that the costs of abatement of any one RATG, let alone the costs for abating different RATGs, will be quite different in different nations. Allowing different nations the flexibility to choose different abatement options allows each nation to design its least costly set of measures to achieve global results -- thus reducing net global costs. The comprehensive approach allows

⁷² R.J. Moulton and K. Andrasko, "Reforestation," 16 EPA Journal 14 (March/April 1990).

such flexibility; a piecemeal approach prevents flexibility across gases, sources and sinks, at higher cost to all.

The socioeconomic costs of policy responses to global climate change could be great. Some studies have indicated that significant emissions reductions would be associated with substantial impairment of economic growth.⁷³ Some nations and some sectors of society could face especially high costs of limiting emissions of trace gases. For some nations, the costs of unduly inflexible piecemeal emissions limits would mean serious deprivation for residents of economies struggling to develop. It is thus imperative that we choose strategies that will maximize nations' flexibility to select least-cost options and that will provide maximum incentives and opportunities for development of new technologies and other innovative responses that will further reduce costs. A comprehensive approach would contribute substantially to achieving this goal.

2. Performance-based incentives

The use of performance-based standards under a comprehensive approach would also improve the economics of response measures. Historically, piecemeal, command-and-control regulations have been implemented by using "design standards" requiring those who emit a substance to apply specific technological controls, such as "best available control technology." That approach has been suggested in the climate context, but it has numerous drawbacks. First, it is insensitive to the costs and benefits of applying each control technology at each site, thus resulting in the same kinds of inefficiencies described above with respect to requiring identical emissions limitations in all nations; environmental protection could be achieved at less cost if limitations were obtained using the least-cost option in each place. Second, it discourages innovation in control technologies, because the mandated "best" technology is "locked in" and innovations are not rewarded. Third, it discourages improvements in raw materials choices and resource use efficiency that would limit the total amount emitted, because requiring application of a specific control technology gives businesses no incentive to conserve fuels or otherwise minimize emissions, once the control technology is in place. These drawbacks make technology standards much less economically efficient than performance-based incentives. The comprehensive approach, by employing a performance-based

⁷³ Several studies are summarized and assessed in Interagency Task Force, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment," U.S. Department of Energy, OPPA, DOE/PE-0096P, September 1990, pp. 23-29.

incentive that leaves the choice of the means to comply to the individual emitter, encourages least-cost, innovative, and resource-efficient responses.

At the same time, performance-based strategies imply good knowledge of performance -- in this case, probably defined by RATG net emissions. Work is needed to improve measurement capabilities, both to predict future RATG concentrations, and to allow performance-based incentives should they be warranted.

B. Social and institutional flexibility.

Taking a comprehensive approach to any emissions limits would reserve to each nation the freedom to employ whatever economic and institutional mechanisms it wishes to use to achieve its objective. Nations would retain the flexibility necessitated by the widely varying legal and cultural systems in different countries. A comprehensive approach would avoid imposing on the autonomy of sovereign states, as would a piecemeal or "design standard" approach that dictates to each nation how it must manage its climate-related policies and sectors.

Under a comprehensive approach, the institutional response of each nation would be its own choice. A free market economy would not be required to employ strict command and control regulations; by the same token, a centrally planned economy would not be required to employ market measures.

In addition to the desire to minimize the costs of achieving any emissions limitation, as described in the previous section, nations may have special needs to continue certain activities intimately tied to their cultures or social systems. A comprehensive approach would be sensitive to these needs, giving nations maximum flexibility to choose their own response options. For example, a mandated CH₄ reduction standard that applied uniformly to all nations would be very intrusive to a nation in which CH₄ derives largely from livestock and the livestock are considered sacred. A piecemeal CH₄ limitation would leave that nation no option but to restrict its herd. Under a comprehensive approach, nations would not be relieved of the obligation to share in any global effort to limit emissions; but by defining the obligation in terms of net RATG emissions and allowing each nation to select its preferred mix of policies that achieve that end, nations would be better shielded from the havoc that could attend an international mandate to disturb deeply rooted social and cultural practices. Instead, nations could choose their steps to limit other RATGs or to address other sources or sinks.

C. "Level playing field."

A piecemeal approach inevitably favors some nations while disproportionately burdening others. For example, a CO₂-only approach penalizes nations with relatively greater dependence on fossil fuels or fossil fuel revenues, while a CH₄-only limit could burden nations who rely on rice as a staple. A comprehensive approach provides a more equitable "level playing field" across nations. A comprehensive approach is consequently likely to avoid some of the obstacles to international agreement that would be faced by a piecemeal gas-by-gas approach, such as "blocking" by nations who feared that the initial burden would fall on them.⁷⁴ The comprehensive approach would ease such fears.

Moreover, experience shows that once adopted, piecemeal initiatives rarely evolve into a comprehensive strategy. Piecemeal measures tend to create constituencies with vested interests that ensure their perpetuation. For example, the Prevention of Significant Deterioration (PSD) provisions, enacted in the early versions of the U.S. Clean Air Act, limit industrial development in many regions of the nation, often without environmental justification. Other regions oppose efforts to relax or rearrange these limits, for fear that industrial and economic development will shift to the regions that are now subject to PSD controls. The result is that the PSD controls remain in place, in their partial form, constraining balanced economic growth.

Similarly, any global climate agreement that aimed at energy sector CO₂ limitations would benefit certain nations relative to others. The favored nations would resist development of a more comprehensive approach that would treat all nations with an even hand. The result would be incomplete environmental protection, the flaws of a piecemeal policy immovably entrenched, and serious economic distortions. It is accordingly vital to ensure a "level playing field" by adopting a comprehensive approach at the outset. It is much better to get the policy design right at the beginning, and to fill in any gaps through hard work, than to start with a defective policy design and be saddled with it indefinitely.

In a related manner, a comprehensive approach reduces the ability of nations to manipulate the design of international

⁷⁴ Compare James Sebenius, "Negotiating a Regime to Control Global Warming," in Greenhouse Warming: Negotiating a Global Regime, World Resources Institute (January 1991), pp. 75-78. Sebenius discusses (and conflates) several ways in which issues for negotiation might be combined to avoid "blocking" coalitions.

regulatory measures to advance their own competitive or other economic advantage. A gas-by-gas command and control approach is vulnerable to attempts by nations to "game" the standard-setting agenda in their favor. For example, a nation reliant on non-fossil fuel energy sources, and whose chief rival earns its income from fossil fuel exports, could press for limits on CO₂ emissions not for their environmental value but to improve its own competitive standing relative to its rival. Or a wheat-growing nation could press for methane emission limits at the expense of its rice-growing neighbor. Such attempts would hinder international agreement on limits on any particular gas. Such attempts to "game" the design of international regulatory controls are also likely to distort trade and reduce global welfare, as well as impede environmental improvement. By leaving the mix of compliance policies to each nation's discretion so long as the overall limit is not exceeded, a comprehensive approach greatly reduces the potential for such gaming. And a comprehensive approach is likely to promote sober consideration of any emissions limitation proposals by all nations, because few nations could evade all responsibility under a comprehensive approach (as some might under a narrow piecemeal approach).

The comprehensive approach thus reduces the likelihood of "blocking" by those who would be disproportionately burdened by piecemeal measures; and it reduces the ability of rival nations to distort the climate protection effort toward their own parochial ends. At the same time, its broad coverage encourages all nations to examine carefully the costs and benefits of any response measures. These advantages suggest that consensus on any warranted steps would be easier to define, and would better reflect real costs and benefits, under a comprehensive approach. A comprehensive approach would then share burdens more equitably, to everyone's gain.

Chapter VII: Potential Objections to a Comprehensive Approach, and Replies

A variety of concerns has been raised about the meaning and use of a comprehensive approach. This chapter addresses the objections most often voiced. None of these objections, nor all taken as a whole, warrants rejection of a comprehensive approach. Indeed, several of the objections simply provide the opportunity to clarify the rationale for and workings of a comprehensive approach, and to explain how a comprehensive approach would better serve environmental and economic goals.

A. "Data and monitoring of sources and sinks are inadequate."

The major objection that has been raised to the comprehensive approach is that the current science is not up to monitoring certain sources and sinks, such as non-point sources of methane and nitrous oxide. The objectors say that we should "do what we can now" and wait until later to design a comprehensive approach. Yet focusing on CO₂ from energy emissions, merely because that is the source most easily measured at present, bespeaks a certain complacency with the current stock of research. Many current studies confine themselves to energy policy alone simply for the reason that, in the words of one of the more candid analysts, "[t]his focus suggests itself because the necessary quantitative data for a least-cost analysis are far more developed in the case of energy than for other major sources of greenhouse gases."⁷⁵ And unless comprehensive research is carried out, a narrow and incomplete knowledge base will yield incomplete and flawed piecemeal policy responses.

The more inquisitive comprehensive approach thirsts for research into the key unknowns. Measuring many such emissions will not be easy. But it is not beyond our reach, if we focus current research efforts to support a comprehensive approach. It is particularly in agriculture and forestry that the research toward improved monitoring is most needed. The net emissions data base is perhaps least well-developed for the diffuse, non-point sources and sinks of greenhouse gases that are typical in the agriculture and forestry sectors. For example, recent studies are advancing understanding of carbon sinks: both the

⁷⁵ F. Krause, et al., Energy Policy in the Greenhouse, (IPSEP / European Environmental Bureau / Dutch Ministry of Housing, Physical Planning and Environment, September 1989), Volume One, p. I.1-3.

total size of the oceanic versus terrestrial sinks,⁷⁶ as well as the more localized effectiveness of different types of forestry in sequestering carbon;⁷⁷ but the uncertainties surrounding these processes are still significant. As to methane, we are beginning to understand its diverse sources in rice cultivation, livestock, the energy sector, and waste disposal,⁷⁸ and its sink in tropospheric chemical reactions; but while we have fairly good data on certain sources such as landfills, the gaps in the data on other sources remain significant. The same holds for nitrous oxide. We will need better estimates of these sources and sinks if we are to forecast future concentrations of the gases, fashion reliable greenhouse gas indices, or calculate baseline and future net emissions for each nation or sector.

The pertinent question, however, is not what is immediately "feasible," but whether the costs of proceeding with a flawed piecemeal policy design are less than the costs of doing the necessary groundwork to develop a comprehensive approach. The groundwork needed to flesh out a workable comprehensive approach is very likely to be less costly than the environmental and economic losses that would attend implementation of a piecemeal approach that is ineffective and inflexible. And as indicated in Section C of Chapter VI, it is better to start with a proper policy design and work hard to fill in any gaps, than to start with a flawed policy design and be stuck with it indefinitely.

And one need not wait for perfection; in the interim, proxy-based estimates of difficult-to-measure emissions could be used. Continuing research, bringing together physical and social scientists with expertise on the critical areas of uncertainty about emissions, is indispensable. International efforts such as the framework convention should build cooperative networks to measure net emissions. International agreements could include incentives for improvements in monitoring, such as offering awards or even emissions credit to those who demonstrate better monitoring techniques.

⁷⁶ See P. Tans, I. Fung, & T. Takahashi, "Observational Constraints on the Global Atmospheric CO₂ Budget," 247 Science, 23 March 1990, p. 1431.

⁷⁷ See M. Harmon, W. Ferrell, & J. Franklin, "Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests," 247 Science, 9 February 1990, p. 699.

⁷⁸ See IPCC Response Strategies Working Group, "Methane Emissions and Opportunities for Control," coordinated by Japan Environment Agency and U.S. EPA (September 1990).

Then, if emissions limits are warranted, a comprehensive approach can be phased in as other actions (e.g. forestry agreement) are integrated, and as the inclusion of harder-to-monitor sources and sinks becomes manageable. Although it is vital to begin with as fully comprehensive an approach as possible, an approach that is substantially comprehensive, in principle covering all RATGs, sources and sinks, could be supplemented with additional items as research and data brought them to a practical stage.

B. "The Global Warming Potential Index is uncertain."

There is emerging international consensus that the scientific fundamentals are sound. Although uncertainties remain in the index values, relating principally to the residence times of gases such as CO₂ and N₂O, the IPCC found general acceptance for its GWP method; and the consensus of an international workshop on GWP Indices organized by NOAA, EPA, NASA, UKDOE and others in Boulder in November 1990 was that although these uncertainties require urgent attention, they do not warrant abandoning the index. Some of the estimates in the GWP index are expected to change as new research is undertaken. For example, recent work shows that the lifetime of CH₄ is 12.5, not 10, raising the GWP of CH₄. The residence time of CO₂ is an estimate because carbon cycles between the ocean and atmosphere every 5-10 years, ultimately sequestered much later. This estimate will probably change as research proceeds. Methodological suggestions may also be made to improve the index.

For practical policy purposes, some index is much better than no index. The major choice is between no index (a piecemeal approach) and a good index; the choice between a good index and a near-flawless index is something more of a luxury. A good but imperfect index could serve well and then be amended later. Absolute precision is not necessary for practical uses, such as providing general guidance to decisionmakers, and affording them the flexibility to select a mix of response options among the several RATGs.

C. "Other discrete actions will have already been taken."

It is inevitable that other discrete actions will already have been taken by the time any climate agreement is signed. These include limits on CFCs in the Montreal Protocol, and could include forthcoming agreements on forestry and on VOCs.

Any international agreement employing the comprehensive approach would be constructed out of a number of institutional building blocks: the several international accords and national actions contemplated or already in place, each of which addresses

a discrete term in the global change equation. Related national actions would similarly be recognized, to avoid giving disincentives to useful measures that nations wish to take for other reasons. Indeed, these actions could be recognized in the convention, to provide incentives in advance for nations to take actions justified on other grounds that also address net RATG emissions.

D. "CFCs should not be included in comprehensive basket."

First, all anthropogenic substances contributing to radiative forcing should be included. Use of CFCs and CFC substitutes (HCFCs, HFCs) in the future may be quite important to radiative forcing, but the Montreal Protocol does not account for these impacts.⁷⁹ Failing to address these radiatively active gases in the climate context could invite perverse environmental results. Far from any "double counting," such an approach would account for the climate impacts of CFCs that the Montreal Protocol omits.

Second, it should be clear that a comprehensive approach to climate change would not allow nations to violate their obligations under the Montreal Protocol. At the same time, reductions more ambitious than required by the Montreal Protocol -- faster reductions, or reductions in other uncontrolled substances, or reductions achieved in nonparty nations -- could earn credit under the climate agreement; this would provide supportive incentives to phase out ozone-depleting substances even more quickly. Consider the incentive effects of the following options for addressing CFCs in an RATG agreement:

- (a) not giving credit for any limitation of CFCs and halons;
- (b) giving credit for limitations of CFCs and halons, to the extent they go beyond the limits required under the Montreal Protocol, and/or for limitation of ozone depleting substances that are also RATGs but that are not covered by the Montreal Protocol; and
- (c) giving credit for all limitation of CFCs and halons to the extent that they are RATGs.

Each of these options would have different effects on CFC consumption. Option (a), no credit, would provide no additional

⁷⁹ See Donald A. Fisher, et al., "Model Calculations of the Relative Effects of CFCs and their Replacements on Stratospheric Ozone," 344 Nature 508 (April 5, 1990); and Fisher, et al., "Model Calculations of the Relative Effects of CFCs and Their Replacements on Global Warming," 344 Nature 523 (April 5, 1990).

incentive to nations producing CFCs and halons to achieve further reductions beyond required limits. Option (b) would provide such an incentive, but by disallowing credit once the limitation is covered by the Montreal Protocol, option (b) would perversely discourage further expansions of the Montreal Protocol. And option (c) would provide such an incentive as well as recognize the value to potential global climate change of limits on CFCs and halons under the Montreal Protocol.

Third, some nations are doing more to reduce global CFCs than others, at their own expense, and their contribution should be recognized.

Fourth, excluding emissions reductions already covered by the Montreal Protocol would reduce the likelihood of attracting new parties to the Montreal Protocol: nations who are not now parties to the Montreal Protocol would face disincentives to joining the Protocol if joining meant that their CFC reductions lost credit under the climate agreement.

Fifth, there is an existing reservoir of CFCs and halons trapped in such containers as abandoned refrigerators. Leaks of such CFCs and halons constitute both ODP and RATG emissions, but are not covered by the Montreal Protocol. Giving credit for reductions in these CFCs would provide helpful incentives to store or recycle such gases safely.

E. "A comprehensive approach is complex and unworkable."

First, a comprehensive approach is not complex or unworkable. A comprehensive approach to research and monitoring is not only workable, it is the only practical approach. As an approach to any agreed emissions limitations, the Montreal Protocol has quite successfully demonstrated the feasibility of employing a multi-gas approach with an index of gases' relative impacts on the environment.

Second, as experience with traditional environmental issues shows, adopting a piecemeal approach means scrambling to redress unintended shifts and dysfunctions. The reality of shifts in traditional environmental contexts, and the potential for shifts in the climate context, elaborated in Chapter V, should indicate the serious workability problems facing a piecemeal approach.

Third, a comprehensive approach would ease the workability and complexity of any agreed emissions limits, by affording economic and institutional flexibility to nations to design their own best mix of response options. Piecemeal measures might be "easier said than done": easier to write down on paper, but harder for diverse nations to implement in light of

their diverse circumstances, needs and capabilities. Further, the comprehensive approach avoids the complex, cumbersome, and bureaucratized central determination of precise uniform gas-by-gas or source-by-source emissions targets, or selection of uniform "best available control technology," some or all of which would likely be called for under a piecemeal approach.

F. "We can't afford to wait for a comprehensive approach; we need to do what we can now to address CO2."

It might be argued by some that employment of the "comprehensive" approach could add delay to the process of reaching international agreement on global climate change issues. Some say that the fastest approach is to adopt protocols quickly for substances we can agree on now, and then proceed to thornier issues as we go.

First, development of a comprehensive approach does not mean delay. It is ready for implementation today in the framework convention, to define the scope and key elements of research and monitoring.

Second, if emissions limits are warranted, a comprehensive approach can be phased in as other actions (e.g. forestry agreement) are integrated, and as the inclusion of harder-to-monitor sources and sinks becomes manageable. Although it is vital to begin with as fully comprehensive an approach as possible, an approach that is substantially comprehensive, in principle covering all RATGs, sources and sinks, could be supplemented with additional items as research and data brought them to a practical stage.

Third, given its environmental and economic advantages, taking the time to develop a comprehensive approach is worthwhile. A piecemeal approach would mean environmental frustration and dysfunction, due to such defects as the potential for unintended shifts of residuals (see Chapter V); adopting a piecemeal approach sooner would probably not be a big improvement. A comprehensive approach could achieve better overall environmental protection than a piecemeal approach, even if it does take slightly longer to achieve than the first single-gas protocol would take.

Fourth, if there is agreement that response measures are warranted, use of a comprehensive approach to policy measures could in fact advance the date of agreement because (as discussed in Chapter VI) it raises the likelihood of broad consensus by eliminating the divisive inequitable effects of a piecemeal approach. Under almost any piecemeal approach, some party would be disproportionately burdened, and would be likely to block

effective agreement; a comprehensive approach would ease the way to equitable and sober consideration of response options.

Fifth, the suggestion that we ought to "do what we can now" is generally incorrect. As discussed extensively under Section A of this Chapter and Section C of Chapter VI, it is better to develop a sound approach at the outset than to launch an approach that is likely to fail at great cost. The framework needs to begin as a comprehensive approach, because starting with a piecemeal approach will likely leave it entrenched, rather than encouraging evolution toward a comprehensive approach. Those who are favored by the initial piecemeal approach would try to block any attempts to broaden its scope.

Sixth, many nations are already taking action. These steps should be accounted for and recognized through a comprehensive approach.

Seventh, a comprehensive approach makes better use of scarce resources, because it achieves results at less cost (see Chapter VI) and because it maximizes the environmental benefit for any investment of social resources. It thus better provides for sustainable development, which requires both effective and efficient policies since environmental protection ultimately depends on the resources that economic growth provides.

Finally, a comprehensive approach does not prevent action. Nations who wish to limit net emissions of any of the range of trace gases may do so now; indeed taking a comprehensive approach broadens the set of opportunities that nations have to act now to address potential climate change.

Chapter VIII: Market-based Incentives

If any emissions limitations are deemed warranted and agreed to, they should allow nations the opportunity to employ, at their voluntary discretion, market-based incentives in implementation. We have learned a great deal about the drawbacks of traditional "command-and-control" regulatory approaches: by mandating uniform adoption of centrally chosen abatement techniques, they raise costs, discourage innovation and resource use efficiency, and raise administrative burdens. The virtues of market-based economic incentives for environmental protection are now increasingly well-recognized. The common feature of the new tools is that they respond to market-failure -- such as excessive pollution -- by redirecting and harnessing market forces to correct the problem. They allow flexibility among market actors, promote decentralized decisionmaking about response tactics, further least-cost solutions by allowing those who can fix the problem most cheaply to do so most, and stimulate efficient resource use and innovation in technologies and practices.

A. Voluntary Use.

Any use of market-based incentives should be at the voluntary election of the nation or nations involved. Domestically, each nation should have the option of employing any implementation mechanisms it prefers. These may include technology development, market-based incentives such as tradeable emissions allowances or fees, conventional regulations, technology standards, or other techniques. Any international agreement to respond to potential climate change should avoid impairing nations' freedom to choose their domestic policy tools.

Internationally, the use of market-based incentives would likewise be voluntary. For example, emissions trading is by its nature a voluntary enterprise. If the opportunity for international emissions trading is left open, it would mean that two or more nations could, at their voluntary election, cooperate on joint activities that together achieve their aggregate international obligation. It would simply allow a nation to achieve its goals abroad as well as at home. Similarly, a grouping of a region of nations, or a grouping of similarly interested nations, could elect to allow trading -- cooperative joint efforts to accomplish aggregate emissions goals -- among the member nations. No nation would be obliged to participate in any mandatory trading "system."

Market-based incentives could be employed under a single-gas approach or a comprehensive approach. Their advantages would be maximized when coupled with a comprehensive approach, since the flexibility of choices among gases, sources,

sinks, and location of investments would magnify the economic and incentive gains.

B. Examining current government interventions.

Before devising new policies, the first step in a market-based approach should be to examine current government policies and their effects on markets relevant to global change. What are their effects on the inputs to global change, and on the ability to adapt to any global change? On the input side, it is often government policies that subsidize activities in the energy, agricultural and forestry sectors and thereby increase net emissions of trace gases. These include counterproductive agricultural price supports and other policies that induce excess crop planting and unduly intensive use of nitrogenous fertilizers, adding to nitrous oxide emissions as well as erecting trade barriers. And they include rules that needlessly encourage even below-cost forest clearing, reducing carbon sinks.⁸⁰ On the adaptation side, policies that prevent the development of efficient markets for natural resources -- such as water -- may undermine the incentives that would be provided to induce conservation if global change put pressure on supplies. Better operation of private markets, on both the input and adaptation side, could help address climate change without major social expenditure.

C. Harnessing market forces toward environmental progress: U.S. experience.

Where market failures demand policy interventions, market-based tools can provide the best response options. Fees, tradeable allowances, and deposit-refund programs have demonstrated success in several important environmental applications, including the tradeable credits program used to phase out lead in gasoline -- achieved at about half the cost of a traditional regulatory program (amounting to savings of hundreds of millions of dollars). Both fees and tradeable allowances are now being used in the U.S. program to phase out CFCs under the Montreal Protocol. And tradeable allowances will be employed in the acid rain reduction provisions of the new Clean Air Act, with projected national savings of \$1 billion annually as compared to a command-and-control program.

The use of market-based instruments for environmental protection is not just the stuff of theory; it is already the

⁸⁰See, e.g., Randall O'Toole, Reforming the Forest Service (1989); Robert Repetto, "Deforestation in the Tropics," 262 Scientific American, April 1990, p. 36.

reality of practical application in the United States and elsewhere. In several areas of environmental policy, market-based instruments such as tradeable allowances, fees, and deposit-refund systems are in place and have been operating with general (and often great) success.

The attractiveness of market-based economic instruments relates to the goal of environmental policy interventions: to correct failures of private markets to achieve society's environmental goals. The background presumption is that private markets will provide the goods and services that consumers desire. But private markets may provide inadequate environmental protection when environmental values are "externalities" not adequately reflected in the prices consumers pay for goods and services, or when environmental values are "public goods" from which all individuals benefit but in which no individual has an adequate incentive to invest.

In remedying such market failures, governments (the United States included) have traditionally employed "command-and-control" regulations. Such regulation relies on uniform, inflexible, technology-based standards that result in high compliance costs, restrict innovation, discourage efficient use of resources, and require detailed central planning of economic activity. While some of these regulatory controls have been initially effective in limiting environmental degradation, they have also proved to be costly and burdensome. Because the cost of controlling pollution varies among those subject to regulation, a command-and-control policy requiring them all to meet the same target, or to install the same technology, means that some could have achieved the same environmental protection outcome through less costly means. Society is consequently forced to pay more for environmental protection than it needs to, wasting resources and potentially arousing resistance to further environmental policy measures. In the longer run, command-and-control regulation deters innovation by selecting a chosen technology and giving no reward to those who devise a better techniques; this in turn weakens the ability of command-and-control regulation to prevent environmental degradation effectively.

Since the underlying problem is that private markets are operating imperfectly, the better approach for government action will often be to "reconstitute" the market: to orient it toward providing incentives that promote the desired environmental outcome. By revising the market's own system of pricing and allocating environmental protection responsibilities, market-based mechanisms turn the power of the marketplace -- the indefatigable creativity of diverse and flexible responses by motivated market actors -- to environmental advantage. Overall social costs are reduced because those who can prevent degradation most cheaply have the most incentive to do so.

Environmental protection is advanced as the incentives spur innovation in technologies and processes, and as efficient use of resources (such as conservation of fuels) is put on equal footing with installation of control technology.

Among the several types of economic instruments that might be used to implement environmental policy, current applications have generally employed a few basic techniques: fees, tradeable allowances (also called marketable permits), and a hybrid form called deposit-refund systems.

A fee can be attached to each unit of emissions, effectively forcing the emitter to "internalize" the cost that the emissions impose on society. Each emitter reduces emissions to the point that its costs of control become as expensive as paying the fee; this point will vary for each emitter, but the aggregate emissions reduction will correspond to the size of the fee exacted.

Under tradeable allowances, a constraint is imposed on the total quantity of emissions, allowances adding up to that total are issued, and emitters are allowed to reallocate allowances among themselves. The aggregate emissions cannot exceed the total level set, but the amount controlled by any individual emitter may vary -- provided that it must hold allowances for each unit of emissions, or face heavy penalties. Those who can control emissions more cheaply free up excess allowances to sell at a profit, while those for whom control is more expensive purchase allowances. The market price of the allowances is effectively similar to a fee on emissions, forcing purchasers to internalize the costs of their excess emissions.

A deposit-refund system is like a fee with a rebate: those who generate a waste, or purchase a product, must pay a deposit on the item; when they return the item for proper treatment, they receive a refund. This arrangement provides an incentive for proper handling, whereas a mandatory return rule could induce illegal disposal to avoid the costs of return.

The United States has used each of these market-based mechanisms as tools to implement environmental policy. This section provides a picture of the great diversity of contexts in which these tools are being applied, and the general features of each program.⁸¹

⁸¹ This discussion draws heavily on Bruce Ackerman and Richard Stewart, "Reforming Environmental Law: The Democratic Case for Market Incentives," 13 Colum. J. Envtl. L. 171 (1988); Robert Hahn and Gordon Hester, "Marketable Permits: Lessons for Theory and Practice," 16 Ecol. L. Q. 361 (1989); Richard Stewart, "Current Experiments with Economic Instruments in Environmental Policy," paper presented at the EDF/AER*X/USSR Academy of Sciences "Soviet-American Conference on Economic (continued...)

1. Current programs.

Emissions trading under the ambient air quality rules of the Clean Air Act: bubbles, netting, and offsets. Under the Clean Air Act, each region of the country must attain ambient air quality standards. Existing, modified, and new sources of emissions are all required to employ emissions controls. Starting in the late 1970s and increasingly in the last decade, the U.S. Environmental Protection Agency (EPA) has employed several different emissions trading programs: "Offsets" allow new sources of emissions to be added to an area (provided they employ stringent control technology) so long as they obtain corresponding decreases in emissions from existing sources in the same area. "Netting" allows an existing source to add a modification that produces additional emissions, without having to install the most stringent emissions control technology, if it obtains a corresponding decrease in emissions from other parts of the same unit. "Bubbles" allow existing plants with emissions emanating from multiple units (such as several smokestacks) to reallocate emissions among the sites within the plant, and existing plants to reallocate emissions among a set of plants, so long as total emissions do not increase. In addition, a banking program lets existing sources store excess reductions in emissions for future use.

Experience has been different under each of these programs, but in general, there have been significant cost savings over traditional regulations. The netting and bubble programs, for example, achieved savings estimated at several billion dollars in the first seven years of the program. And these substantial savings have been obtained despite the fact that the trading program is a modest modification to a traditional, command-and-control technology design regulatory program. Meanwhile, no reduction in environmental quality has been observed; there has been no increase in the aggregate emissions level.

Lead phasedown: content reduction credits. Also under the Clean Air Act, the EPA issued regulations reducing the allowable lead content of gasoline. In 1982 EPA instituted limits on lead content and permitted trading within and among refiners: leaded gasoline producers and importers could transfer (i.e., buy and sell) lead content credits freely among themselves through 1986, or could apply such credits to their own gasoline. But such credits expired quarterly if unused. In 1985, EPA

81(...continued)

Instruments for Environmental Protection," Washington D.C., November 12, 1990; and James Tripp and Daniel Dudek, "Institutional Guidelines for Designing Successful Transferable Rights Programs," 6 Yale J. Regulation 369 (1989).

substantially reduced the lead content limit further; the content was required to decline, in phases, from 1.10 grams of lead per gallon (gpg) to no more than 0.10 gpg by the end of 1985. To provide leaded gasoline producers and importers with some flexibility in complying with the new limits, EPA also issued regulations in 1985 permitting producers and importers whose gasoline in 1985 contained less lead per gallon than the applicable standard, to "bank" lead content credits (i.e., to avoid the expiration of credits). The "banking" regulations then permitted gasoline producers and importers to "withdraw" those lead content credits through the end of 1987 and to apply them to help meet the new, more stringent lead content standards that took effect in 1985.

The banking and trading system helped the industry as a whole to comply with the new lead limits, while ensuring that the total amount of lead content did not exceed the maximum that otherwise would have been allowed under the lead content standards in the absence of the banking provisions. Data indicate that banking and trading were active, and that they resulted in substantial cost savings (on the order of hundreds of millions of dollars over the few years of the program).

The design of the lead phasedown facilitated widespread trading. Firms were not required to apply to the EPA for permission to enter into trades; they simply reported their trades to the government, as part of their regularly required reports of the lead content in their gasoline. Each firm was simply required to have a net balance of lead content credits greater than or equal to zero in each quarter. In addition, because gasoline refiners and importers were accustomed to trading feedstocks and other commodities with each other, trades in lead content credits did not require new information networks. In sum, the lead phasedown was highly successful.

CFCs reduction: production allowances. Both trading and taxes are being used in the effort to phase out chlorofluorocarbons (CFCs) in order to protect the stratospheric ozone layer. Internationally, the 1987 Montreal Protocol obliges each nation to cut in half its consumption of CFCs by 2000; the 1990 update of the Protocol accelerates that schedule to a total phaseout by 2000. The Protocol allows a small amount of trading among nations in CFC production, a flexibility that was expanded in the 1990 update. To date little if any trading under this provision has occurred, probably because the Protocol explicitly constrains the extent of the trading, and also because trading is only allowed in production (i.e. in the physical location of production facilities) and not in consumption (defined as production plus imports less exports).

Domestically, in order to implement the first phase of the 1987 Montreal Protocol and the national legislation following from it, the U.S. EPA has issued regulations requiring the 50% phaseout by 2000 and implementing the phaseout by issuing allowances to each producer and importer of CFCs. These

allowances may be traded among producers, importers and other interested parties. EPA is able to monitor production and imports of CFCs, and to keep track of allowance trades. Producers are aware of potential buyers and sellers and can trade allowances freely. But the small number of producers and importers may limit the number of trades that actually occur.

It is sometimes assumed that market-based instruments are a substitute for tough enforcement programs, which they are not. As indicated earlier, tradeable allowance systems depend on preventing emitters from emitting more than the allowances they hold. The CFCs program is a good example of our vigorous enforcement efforts: this past summer we brought the first enforcement actions by any government worldwide, so far as we know, to enforce compliance with obligations under the Montreal Protocol. We sued six companies for importing CFCs without obtaining allowances; the violators were required to purchase allowances on the open market and in addition to pay penalties.

In addition to issuing CFC allowances, the United States has imposed an excise tax on CFC production and importation. Like the allowance trading system, this tax will encourage the transition to higher-priced substitutes for CFCs. The tax is a multiple of the ODP value for each CFC, calibrating the incentive to the environmental impact of the substance.

An important issue in protecting the earth's ozone layer is the large reservoir of CFCs remaining stored in coolant systems and other end uses. The tax and tradeable allowance systems will provide some incentives to recover and recycle old CFCs, but a direct refund might be offered to encourage more recovery.

Pinelands development: tradeable development rights.

A somewhat different kind of allowance approach has been used successfully by the State of New Jersey to regulate development of the Pinelands, a forest zone the State wishes to protect from excessive development. Here the allowances are not for emissions, but for rights to develop certain property. Property in parts of the Pinelands is slated for preservation, and the owners of that property may agree to be prohibited from developing their land. In return, they are issued "transferable development rights" (TDRs) which they may sell to others wishing to develop land in the other areas of the Pinelands. Different amounts of TDRs are issued to each owner, depending on the value to society of preserving that owner's property. In areas in which development is permitted, landowners must hold TDRs to develop their property. Thus, the total amount of development in the Pinelands is capped, and the regional distribution is partly restricted; but the precise allocation of development on permissible properties is left to the market for TDRs. In addition, no current landowner is entirely deprived of the former market value of his or her land, because those who are barred from developing their own land receive TDRs to sell to others. The government has established a TDR exchange to facilitate

trades: the exchange buys TDRs from willing sellers and sells them to interested buyers.

Fox River water quality: discharge renegotiations. Under the Clean Water Act, sources of discharges into water supplies must meet emissions limits to achieve water quality standards. The State of Wisconsin adopted a discharge limit system for the Fox River that set the limit for each source, but also permitted sources to devise new discharge limits, by mutual agreement, so long as the total discharge did not rise. In principle, the plan implements a market in transferable emissions allowances. In practice, however, the system has proved cumbersome. Sources hold five-year permits from the state, and trades may expire at the close of a permit cycle, impairing their use for reallocations that involve long-term investments in capital equipment. No allowances or credits are actually issued to sources; instead, each agreement between sources must be submitted for approval to the state agency. Parties must demonstrate to the state that they "need" to make changes in their permits. Review by the agency can be complex and time-consuming. And there is no broker to help arrange trades. Thus, transaction costs are high and the market is sluggish. Agency review of proposed trades is deemed necessary, moreover, by the fact that agreements between sources can yield very low discharges of toxic substances in one local area and very high discharges of toxics in another, potentially placing too great an ecological burden on the latter area. Hence the spectrum of possible trades is limited, and few trades have occurred.

Dillon Reservoir water quality: point/nonpoint trades. In the state of Colorado, discharges from economic activity were endangering the drinking water supplies in the Dillon Reservoir. Emissions came from both point sources (e.g. factory discharge pipes) and nonpoint sources (e.g. runoff). The government issued annual discharge allowances to all sources. It then required that sources may increase their discharges only if they acquire allowances from nonpoint sources, at a ratio of 2:1. That is, for each pound of discharges a source wishes to add, it must reduce discharges by two pounds from nonpoint sources. Because control of point sources is about seven times as expensive as control of nonpoint sources, the 2:1 trading ratio leaves dischargers considerable room for cost-saving trades. Thus, trading will likely both save costs and reduce emissions. Although the program is just getting under way, observers expect active trading and significant cost savings.

Beverage containers: deposit-refunds. In order to reduce litter and encourage recycling of glass and aluminum beverage containers, several states have enacted "bottle bills." These laws institute a deposit-refund system for bottles and cans, in which a deposit (typically 5 cents per container) is charged at the point of purchase and is refunded upon delivery of

the containers to a retailer or recycling depot. Although these programs may reduce litter, they typically charge the same deposit regardless of the type of container (e.g. metal or plastic) and thus fail to provide incentives to consumers to choose the material whose disposal is least costly to society. And the social desirability of these deposit-refund systems depends on how much time consumers must spend returning the containers; curbside pickup programs could be preferable.

Debt-for-nature swaps: international environmental trading. Arrangements in which banks forgive debt in return for the debtor's agreement to conserve natural resources, dubbed "debt-for-nature swaps," are a kind of trading applied to environmental protection. These ad hoc arrangements are not a government "program"; rather they illustrate that private markets can offer mutual benefits to the trading of one asset (debt) for another (environmental protection). A few such swaps have occurred to date. These swaps might serve as a model for more institutionalized international trading on global environmental issues.

2. Programs about to be implemented.

Administration plan to reduce acid precipitation: tradeable allowances. The Bush Administration proposed, and Congress has just enacted, new Clean Air Act legislation to reduce emissions of materials that contribute to acid precipitation. A key feature of the Administration plan is the use of transferable emission allowances. The law sets a permanent cap on emissions of sulfur dioxide (SO₂) (one of the main precursors of acid precipitation) from fossil fuel-burning electric utilities larger than 25 megawatts (the primary source of SO₂ emissions in the U.S.). Initially, annual emissions allowances will be issued to existing utilities in two phases according to a formula that multiplies each plant's historic energy capacity factor by a target average SO₂ emissions rate which is generally lower than the current actual average emissions rate. Under this formula, utilities operating plants with high emissions would not be allocated enough allowances to cover their emissions at historical levels.

To make up this allowance shortfall, which will amount to about 10 million tons of SO₂ per year, individual utilities could reduce their emissions by switching to cleaner fuels, installing additional emissions control equipment or taking conservation measures, or could purchase additional allowances; overall, the industry as a whole will reduce emissions by 10 million tons. Utilities that can afford to reduce their emissions below the target average emissions rate (i.e. below the number of allowances they have been allocated) will be able to sell those "extra" allowances as "credits" to other utilities for whom purchasing allowances is cheaper than investing in emissions

reductions. New entrants to the electricity industry can acquire allowances from existing utilities, or from occasional auctions of a small percentage of allowances reserved by the government.

The cost savings of this trading plan over a plan not employing trading are estimated at about one billion dollars per year or higher. This plan also creates a strong financial incentive for utilities to engage in energy conservation and technological innovation, whereas both would be discouraged by a rule requiring utilities to adopt specific emissions control mechanisms such as scrubbers.

Clam and quahog harvesting: individual transferable quotas. Traditionally, harvesting of surf clam and quahog (a related species) off the East coast of the U.S. have been capped at an aggregate amount; but individual boats' quahog fishing had been otherwise generally unregulated while certain aspects of individual boats' surf clam fishing (such as the frequency of outings and their length) had been carefully regulated. A new program has been developed to employ trading to allocate harvesting activities more efficiently. Under the recent "Amendment 8" to the Fisheries Management Plan for the Mid-Atlantic region of the United States, a system of "individual transferable quotas" (ITQs) for clams and quahogs will be created, with each ITQ representing a percentage of each market. They are initially to be issued to each vessel based on the vessel's historical fishing. The ITQs may then be traded among vessels. This plan has recently been challenged on a variety of legal grounds by plaintiffs including vessel owners and seafood processors.

Mobile sources: averaging, banking and trading. Mobile sources (vehicles) consume fuel and emit pollutants, and trading is being employed in programs to limit both of these activities.

A kind of "internal" trading (trading within a firm) is already allowed under the rules requiring vehicles to attain fuel economy (miles per gallon) standards. The government might have required every individual vehicle to achieve a specified minimum fuel economy standard. Instead, the "Corporate Average Fuel Economy" (CAFE) rules govern the average efficiency of each manufacturer's entire fleet in each model year. This gives the manufacturer flexibility to reach the same aggregate fuel economy while varying the characteristics of each vehicle to suit the spectrum of consumer needs and tastes.

Even more flexibility could be obtained if fuel economy achievements could be tradeable among manufacturers: if one manufacturer who achieved a fleet average lower than the applicable CAFE rule could sell its excess as a "credit" to another manufacturer whose fleet exceeded the rule.

Along these lines, EPA has recently revised its Clean Air Act program governing the particulate and nitrogen oxides emissions of heavy-duty truck engines. For several years EPA has set an average emissions standard for the line of truck engines

produced by each manufacturer, thus affording each manufacturer the internal flexibility to make a range of engines so long as their average cleanliness meets the standard (similar to the CAFE program for fuel efficiency). In its new regulation, EPA now allows emissions trading among manufacturers and banking over time. EPA provides that a manufacturer whose line of engines emits less on average than the standard will earn "credits" which can be banked for application to future model years, or traded to other engine manufacturers. The greatest emissions reductions will be achieved by those manufacturers who can do so at least cost, reducing the overall social cost of the program. And manufacturers will have additional incentives to reduce emissions in order to generate credits to sell at a profit. In an effort to provide assurance that the trading and banking program will not impair environmental protection, EPA is providing that credits will be redeemable at 80% of their face value, reducing by 20% the emissions allowed upon each trade, but also reducing somewhat the attractiveness of investment in additional emissions reductions. EPA projects that the profits from credit sales will still be sufficient to stimulate trades and emissions reductions even with the 20% discount.

Other air quality programs. The 1990 Clean Air Act amendments call for the establishment of other programs in which the trading of marketable allowances is envisioned. One such program is the clean fuel vehicles program, requiring both manufacture of vehicles capable of using cleaner fuels, and purchase of such vehicles by owners of vehicle fleets. Under each part of the program, those who make or purchase more clean fuels vehicles would receive tradeable credits. Another program requires sale of cleaner fuels, including cleaner gasoline, reformulated gasoline, and oxygenated fuels, to reduce VOCs, CO, and toxic air pollutants; it awards tradeable credits for those who exceed production targets.

3. Programs under discussion.

Municipal solid waste. The large volume of municipal solid wastes is prompting concern that landfill capacity will run out. As landfills have become scarce, some of the waste stream has been diverted toward incineration, but that route can pose air pollution problems and generates incinerator ash. Another option might be water disposal in lakes or seas, but tight rules already constrain that possibility. Command-and-control regulation to specify the technology and design of landfills and incinerators can offer some improvements in those facilities, but is not likely to affect the total stream of solid waste directly, and can simply shift wastes from land disposal to air incineration. Mandating that residents separate materials for recycling can also be useful, but does not assure a market for

the recyclable materials and does not directly discourage generation of waste by residents.

One proposal to address these problems is to impose a cost on the generation of solid waste that reflects its social cost of disposal. Such a fee would provide an incentive to reduce the total volume of wastes produced, not just to shift it from land to air to water. The harder questions are how to set the fee and where to assess it. The marginal social cost of disposal may vary from one community to another, so the fee may need to vary across localities, but the products that become solid waste are generally produced and sold in a national retail market. Assessing the fee at the curbside (the point where households put their trash out for pickup) can be successful, as it has been in cities such as Seattle, Washington and Perkasie, Pennsylvania, where a fee is assessed per container (barrel or bag) on the trash that households set out for pickup. But these programs have some difficulty calibrating the fee to the unique disposal costs of each specific material being discarded. Another option⁸² is to assess the fee at the point of purchase, by charging a disposal cost on each retail item according to its ingredients and packaging, and reflecting that cost on the receipt the customer receives from the store. This option is facilitated by the use of computerized cash registers and optical scanners that read a "bar code" printed on the package; the disposal fee can then be programmed into the cash register's computerized price list, and revised periodically or by locality to reflect changing costs. Optical scanners and computerized cash registers are now in use in over half of the retail supermarkets in the U.S. But this option has the drawback that it is difficult to predict in advance how the product will be handled after purchase -- discarded, incinerated, or recycled. Perhaps some combination of local curbside fees and point-of-purchase fees would perform best.

Hazardous wastes. For several types of hazardous wastes, such as lead-acid batteries and solvents, it is important not only to reduce total quantities generated but also to ensure that whatever is generated is carefully handled. Prohibiting landfill disposal of such substances, or mandating disposal in certain designated sites, can lead to "midnight dumping" and other socially damaging evasive tactics. An alternative, market-based option is the use of deposit-refund systems to encourage proper disposal. A deposit is charged on the sale of the item, which is refunded when the item is returned to the retailer or treatment facility. This gives the purchaser an incentive to return the waste properly, not to discard it randomly. Deposit-refund systems for lead-acid batteries are now operated by the

⁸² See Peter Menell, "Beyond the Throw-Away Society: An Incentive Approach to Regulating Municipal Solid Waste," 17 Ecol. L.Q. 655 (1990).

states of Maine and Rhode Island. One possible difficulty with offering a refund on returned batteries is that it might encourage theft of batteries; various measures, such as lockable battery cases, or requiring a receipt to be presented with the battery, could be used to deter theft.

D. Harnessing market forces to address climate change.

If the threat of global change is a market failure worthy of policy intervention, then market-based incentive techniques are especially well-suited to implementing limitation measures for trace gases contributing to global change. The current U.S. policy to phase out CFCs is a prime example of this approach. Because trace gas 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 some restraint on total emissions -- a limit on the net quantity emitted, or a fee on each unit emitted -- but then letting the market allocate the burden of mitigative measures to those who can most easily shoulder it. Because the trace gases mix essentially globally and have essentially only global impacts, the possibility under market-based incentives that the spatial distribution of emissions may become uneven -- called "hotspots" in the context of toxic substances -- would not be of concern.

In the context of limiting inputs to global change, two main economic instruments have been suggested: tradeable emissions allowances, and emissions fees. Both instruments hold the potential for achieving environmental goals at least cost. Tradeable allowances 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 are relatively more expensive will buy allowances, while those who can achieve them cheaply will sell allowances. This gives an incentive to each emitter to develop new means of limiting emissions at less cost than its competitors, so that it can sell its allowances at a profit. The choice of response tactics -- emissions controls, efficient use of fuels and other inputs, and innovation of new emissions limitations techniques -- is left to the emitter. The market allocates abatement actions to those who do so at least cost, reducing the overall cost to society.

Trading could be employed domestically (within a nation) by nations taking steps to limit their emissions of trace gases, as we are using trading in the new Clean Air Act acid

deposition program and in the phaseout of CFCs.⁸³ Thus, any nation that decided to limit its emissions of one or more RATGs could allow emitters within its borders to trade their emissions allowances.

Allowing the opportunity for voluntary reallocations among nations of any agreed international obligations would also be advantageous. Such trades could consist of informal, bilateral reallocations of any obligations to limit net emissions. One nation could satisfy such obligations by investing in response actions in another, with the latter's consent. Any such reallocations would be entirely at the discretion of the participating nations; no nation would be obliged to participate. For example, nation A might approach nation B with a proposal: A will provide new energy technology or agricultural research to B, if B will assign to A some of the resulting emissions reductions. Given the significant international variations in the marginal costs of RATG abatement, the opportunity for such trades would likely enable the world economy to realize substantial cost savings. Limited international CFCs trading of this sort is now authorized under the Montreal Protocol, but it remains to be seen whether the Protocol's strictures on trading will leave room for market activities.

Such trading would also serve as a market-based, decentralized vehicle for introducing needed technology into the developing world. Developing countries could exchange excess emissions allowances for low- or non-RATG-emitting technology from industrialized nations; thus, the developing nation would receive needed resources and a means to pursue economic growth without emitting RATGs. This system would reduce global emissions, while pointing technology toward those who needed it most and stimulating innovation by industrialized nations of technologies useful in developing nations. At the same time, this framework could obviate creation of a heavily bureaucratized, centralized regulatory authority and technology assistance fund that would be less efficient at routing needed resources and technology to recipients.

Emissions fees are another important option. The fee could be calibrated to the environmental impacts index value of the net emissions activity. Like emissions trading, emissions fees offer a least-cost solution that promotes innovation and efficient resource use. Such a plan could make excellent sense

⁸³ See U.S. EPA, "Protection of Stratospheric Ozone," 53 Fed. Reg. 30,566 (1988) (to be codified at 40 C.F.R. pt. 82) (Final Rule) (capping CFC production with marketable permits); 53 Fed. Reg. 30,604 (1988) (Advance Notice of Proposed Rulemaking) (proposing allocation of permits).

domestically, especially where the focus is on specifying the cost of a limitation program more precisely than the quantity of emissions avoided, or where revenue raising is a major goal. Indeed, the U.S. is employing fees on CFCs in addition to tradeable allowances. International application of a fee would raise many more difficult questions: Would nations cede their sovereignty to an international tax authority? How would the fee be set in light of varying effective marginal tax rates, and diverse taxation structures, across nations? How would the potentially enormous revenues raised be allotted and expended?

Market-based incentives could also 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 global change risks (such as 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 (coastal erosion) insurance, or by fostering a market in water resources that provides incentives for efficient use and long-range risk management.

CONCLUSION

Toward a Comprehensive Approach

Addressing the potential problems of global climate change will require creative thinking. Treating the causal factors of global climate change in a piecemeal fashion, gas-by-gas and source-by-source, would ignore the science of climate, jeopardize sound environmental protection, squander scarce resources, and impose inequitable burdens and unreasonably uniform requirements on nations with diverse needs and capabilities. Instead, a "comprehensive" approach to addressing potential global climate change, treating all radiatively active trace gases, their sources and sinks collectively, should be employed in any international agreements addressing potential climate change. Such a comprehensive approach provides a better understanding of human interactions with climate, and, if policy responses are deemed warranted, the means to achieve real environmental quality improvements while preserving economic and institutional flexibility.

Several steps could be taken to incorporate a comprehensive approach into the framework convention on climate change. As described earlier, the comprehensive approach has multiple applications. Each could be incorporated into the work of the IPCC, the convention, and any program the convention establishes. For example, the convention could charge the IPCC or other body to coordinate and assess work on the following:

Research strategy. The convention could advance integrated scientific and economics research on a comprehensive basis, ensuring attention to the sources, sinks, atmospheric properties, and socioeconomic and ecological impacts of all the relevant trace gases.

Monitoring. The convention could spur development of techniques and systems for comprehensive source and sink monitoring, such as cooperative international networks measuring emissions and uptake of all relevant trace gases. It could establish centers for data sharing, harmonizing methodologies, and research & development of new techniques.

International inventories. The convention could help build the capacity to estimate international net emissions of relevant trace gases, including baseline levels and changes due to policy actions. It could provide for national reporting, and for workshops to compare and improve data and methods.

Indices. The convention could continue the IPCC's cooperative development and refinement of indices. It could

charge the IPCC or other body to conduct regular assessments and to keep policy makers informed of developments.

Technology evaluation. The convention could employ a comprehensive approach to assess the net emissions impact of any technology transfer and financial assistance activities. This would provide guidance to maximize the environmental benefits of any such projects.

The convention could also:

Ensure a comprehensive framework for policy. It could provide that any policy discussion, any calls for "national plans," or any limitations obligations (if any, whether now or in the future), are (will be) defined in terms of a comprehensive approach.

Offer incentives through advance assurance. The convention could give advance assurance that current actions will receive credit against any future obligations, in accordance with a comprehensive approach. This would help avoid disincentives to nations taking actions justified on other grounds, which nations may hold in abeyance until credit for them is assured. Actions could include such measures as afforestation, energy conservation, and trace gas reductions, and both national and international programs.

Following a comprehensive approach in the framework convention on climate change would be a substantial scientific, environmental and economic advance in the effort to address complex environmental issues.

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COUNCIL OF ECONOMIC ADVISERS
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON

MEMBER OF THE COUNCIL

January 29, 1991

MEMORANDUM FOR RICHARD PORTER

FROM: RICHARD SCHMALENSEE *RS*
HOWARD GRUENSPECHT *HG*

SUBJECT: Talking Points on Mitchell Resolution

- o The resolution calls, at its core, for the United States to seek an agreement for carbon dioxide emissions reduction among the industrialized countries. Even if strong action to deal with a possible global warming was warranted, such an agreement would make no sense.
- o Scientific and economic uncertainties are so large that we should not bet the economy on this issue. Rather, a strategy of action across a broad front combined with research to address these uncertainties should be pursued.
- o The United States should not let itself be stampeded [by radical environmentalists, or] by foreign governments that talk big or do little or nothing.
 - While other countries merely talk, the United States has already taken significant actions, through the recently enacted Clean Air Act and other policies, that will substantially lower our emissions of all greenhouse gases.
 - Many of the foreign commitments mentioned in the resolution are highly conditional; others like the French proposal, would actually provide room for some countries (France) to increase carbon dioxide emissions while others (the United States) are forced to reduce.
- o An exclusive focus on emissions of carbon dioxide from the energy sector ignores less costly approaches to reduce the overall human contribution to rising greenhouse gas concentrations.
 - The Intergovernmental Panel and Climate Change (IPCC) and the Heads of State of the major industrialized countries (G-7) have endorsed the adoption of a comprehensive approach to the climate change issue.

- The development of enhanced greenhouse gas sinks, such as forests, or reductions in other greenhouse emissions, can be more effective and less costly than carbon dioxide limitations.
- A focus on industrialized country emissions alone will have no measurable impact on greenhouse gas concentrations unless developing countries, whose greenhouse emissions are expected to grow rapidly, participate.
- o Carbon dioxide targets could adversely affect U.S. competitiveness with other industrialized countries.
 - Coal, which is 60 to 70 percent carbon, would be hardest hit by any system of carbon dioxide targets. The United States has abundant reserves of coal, which many countries that are clamoring for carbon dioxide ceilings do not.
 - In 1986, the United States generated 56.2 percent of its electricity using coal. The corresponding figures for Canada, France, Japan, the Netherlands, and Sweden were 15.7 percent, 9.7 percent, 14.7 percent, 26.8 percent, and 3.0 percent.
 - Electricity prices in the United States will be disproportionately affected by carbon dioxide targets.
- o Any system of carbon dioxide emissions targets would have a huge adverse effect on production and employment in the domestic coal industry.
 - This effect would dwarf the effects of the recently and hotly debated Clean Air Act, which merely shifted coal mining production and employment from high-sulfur to low-sulfur coal regions.
 - The export market for coal would almost certainly collapse.
 - For some carbon dioxide targets, the use of coal might have to be phased out entirely.
- o The resolution suggests that carbon dioxide emissions targets can be met at low- or no- cost; the best available information suggests otherwise:
 - Estimates of near-term annual costs for holding year emissions at present levels over the next two decades, which are highly dependent upon baseline assumptions regarding economic growth, energy prices, and technology,

as well as the design of each econometric model, range from 0.5 percent of GNP to upwards of 1 percent of GNP--equal to more than \$70 billion.

- These studies generally presume that efforts to reduce carbon dioxide emissions are pursued in an efficient manner. If inefficient methods are used, as Congress so often requires, the costs of CO2 reductions would be significantly higher.
- The costs of even efficient reductions would far exceed the costs of the recent Clean Air legislation. Indeed, \$70 billion per year is only about \$10 billion less than our current level of spending on all U.S. environmental programs.
- What do we get for this doubling (or more) of our environmental costs. We don't even have an estimate of benefits, which will depend on the actions of other industrialized and developing countries, the sensitivity of the climate to greenhouse gas concentrations, and the sensitivity of human and natural systems to any climate change that may occur.
- The range of cost estimates cited above is not peculiar to U.S. analyses: studies conducted by other countries (Australia, Japan, Netherlands) support this conclusion.
- Beyond 2010, available long-run studies place the costs of an efficient stabilization of CO2 in the range of 1 to 3 percent of GNP.
- Maintenance of a constant carbon dioxide emissions level against a growing baseline would require, over time, an increasingly large percentage reduction from that baseline, tending to raise costs.
- o As the President has often stated, both economic growth and environmental quality are important to the well-being of present and future generations. As global stewards and stewards of this nation, it would simply be irresponsible to ask our President to make premature and ill-considered commitments that are more likely to harm rather than advance our interests.
- o In short, the proposed resolution suggests that we impose huge costs on American consumers, workers, and firms, through adoption of an approach recognized to be inefficient by much of the world to address a problem that may or may not be real. [We should take care not to crucify the citizens of this nation, and all humanity on this planet, on a cross of carbon.]

* DRAFT 2/1/91 *

AGENDA for "FRIDAY SEMINAR"
on Comprehensive Approach to Climate Change

Lincoln Theatre, Westfield's Conf. Center

Friday, February 8, 1991

6:00 p.m. - 7:00 p.m.

6:00 p.m. Welcome

Dick Stewart
Assistant Attorney General
Environment & Natural Resources
Chair, Task Force on Comp. Approach

6:05 p.m. Brief Presentations

Introduction: C. Boyden Gray, Counsel to the President

Scientific Basis:

Dr. Daniel Albritton, Director, Aeronomy
Environmental Research Laboratory,
National Oceanographic and Atmospheric
Administration

Economics of Comprehensive Approach:

Richard Schmalensee, Member, Council of
Economic Advisers

6:25 p.m. Audience Discussion

Moderator: Dick Stewart (DOJ)

Panel to answer questions:

Boyden Gray (WHC)
Dan Albritton (NOAA)
Bob Watson (NASA)
Dick Schmalensee (CEA)
Dick Morgenstern (EPA) or
Dennis Tirpak (EPA)
Ted Williams (DOE) or
Rick Bradley (DOE)

2/1/91

Draft Informal Seminar for Foreign Delegates: Plan

What: An informal discussion of the US approach, primarily our "comprehensive approach." Key is opportunity for informal discussion. All speakers seated at same large table as invitees, if possible; not intimidating. Most of time set aside for question and answer.

Topics: Focus on science, research, monitoring, economics, potential policy design. Less attention to emissions trading here because emissions trading may imply agreement to some limit on emissions.

When: During Negotiations, in February. Plan:

Date of choice is Friday Feb. 8, 6:00-7:00 p.m. (An industry-sponsored reception scheduled this night has been moved to Monday 2/11.) Note that the Japanese are considering some reception this night; State is coordinating with Japan to avoid a time conflict. Some foreign delegates may depart for dinner on Friday night, after a long week of negotiations; but the combination of US and Japanese receptions could hold their interest.

Fallback options: (1) Sunday Feb. 10, 8 p.m. Delegates will be on sightseeing tours on Sunday in Virginia and Washington; as they return to the conference center they could attend a low-key seminar. If delegates remain on tour late Sunday they may miss the seminar, but the tour buses are scheduled to return to the conference center by 5:30 p.m.

(2) Tuesday Feb. 12, 6 p.m. This night is open on the negotiations agenda, but could be occupied by late negotiating sessions (which end on Thursday 2/14).

Where: In Virginia. State Dept. suggests the "Lincoln Theatre" at the Westfield's conference center. Seats 250, with a panel in front of the audience. Will also be used for other receptions during the negotiations.

If in Washington, our choices are numerous. Holding the seminar in Washington means travel time, money.

-2-

Invitees: Because a key element is the opportunity for informal discussion, the session could be kept limited to select foreign delegates only, to prevent overcrowding. But selective invitations could seem rude; there is no pre-defined smaller group of negotiators, along the lines of the IPCC/RSWG we met with last February, to select here.

Choosing a night like Friday or Sunday could result in self-selection that keeps numbers down. Similarly, choosing a small room could keep numbers manageable.

Invitations would be distributed by flyer at the negotiations.

As to US invitees, their numbers must be held down to prevent overwhelming our invited foreign guests (unless foreign participation is open to all).

Funding: For food, location(?), transportation(?).

Speakers: Hosted by Dick Stewart. Speakers: Boyden Gray on overall approach; Dan Albritton (NOAA) or Bob Watson (NASA) on science; Dick Schmalensee (CEA) on economics.

Note that other delegations (Sweden, Japan) and NGOs and industry are making presentations (NGOs, chaired by Rafe Pomerance at WRI and Dan Lashof at NRDC, will present their views on Thursday 2/7; industry will host a reception on Monday 2/11).

Attachments:

- (1) Copy of Agenda from the Feb. 3, 1990 "Informal Seminar" for IPCC/RSWG Officers
- (2) List of "Special Events" during Framework Convention negotiations, Feb. 3 - 15, 1991

SENATE RESOLUTION ON GLOBAL CLIMATE CHANGE

- The focus in the resolution CO2 alone doesn't make environmental sense. What matters for the environment is total net emissions of all greenhouse gases. Beyond that, man-made (anthropogenic) emissions account for only 4 % of the global CO2 flux. So one cannot ignore natural sources and sinks of CO2 as well. We should take a comprehensive approach that includes *all* sources and sinks.
- While other countries have made rhetorical commitments to targets and timetables at various international meetings, the **U.S. HAS ALREADY TAKEN SEVERAL MAJOR LEGISLATIVE AND ADMINISTRATIVE ACTION STEPS TO REDUCE GREENHOUSE GAS EMISSIONS.**
- U.S. Action Steps Include:
 - Legislation to *phase out fully the production of CFC's* and other major ozone-depleting chemicals. In fact, under the Clean Air Act, the U.S. will phase out these chemicals on a faster schedule than required by the amended Montreal Protocol.
 - A *tax on CFC production* (enacted in the Reconciliation bill of 1989) which will result in a faster phase-out than any other country. Already, in the last year, the U.S. has reduced CFC production to 23% below what is required by the Protocol.
 - Major reductions in not only SO2 but also CO2 from electric utilities under the Clean Air Act. By enacting a bill that included a cap on SO2 emissions at sharply reduced levels, and freedom of choice for utilities in how to make the reductions, *the Clean Air bill created a powerful incentive for conservation in the electric utility sector.*
 - The *Clean Air Act* will also sharply reduce emissions of carbon monoxide, nitrogen oxides, volatile organic compounds, and other greenhouse gases or greenhouse gas precursors.
 - The President's program to *plant a billion trees per year* (not fully funded by the Congress in 1991) has the potential to reduce net emissions of greenhouse gases by 50 million tons of carbon equivalent by 2010.
 - DOE has already issued *standards requiring energy efficiency in household appliances* such as refrigerators, freezers, clothes washers and dryers, and dishwashers, the biggest users of energy in the home aside from heating. The National Energy Strategy will include further recommendations for building efficiency and lighting efficiency.
 - The Administration is increasing funding for *R&D into energy technologies* that will reduce greenhouse gases. This includes support for nuclear power, electric battery-powered cars, solar photovoltaics, and alternative fuels.
- In total, because of these policy actions by the U.S. government, EPA estimates that U.S. greenhouse gas emissions in 2000 will be below what they were in 1987 (or today). Very few other countries can make a similar claim.
- In addition, the U.S. has the world's largest program of scientific research to support sound policymaking on global climate change. Funded this year at \$1 billion, the U.S. effort comprises about 50% of the worldwide total being spent to investigate this problem.
- In fact, since 1973, U.S. CO2 emissions have been essentially stable (they have increased by 2.7% in a decade and a half), at a time when U.S. GNP has grown by almost 50%. During this time of stable U.S. emissions, worldwide CO2 emissions have grown sharply. The problem cannot be solved with CO2 reductions from the industrialized countries alone; *all* countries must be involved.

Kelly
Jeff Holmstead
Rm 112

February 1, 1991

Dear Delegates:

It is with great pleasure that I welcome you to the United States as we gather to begin negotiations on a landmark international convention on climate change. This agreement will serve as a framework for future cooperative efforts to address the problem of climate change

We look forward to working with you in the task of addressing this vitally important set of problems. I assure you that 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 to be convened in June 1992.

The UN's Intergovernmental Panel on Climate Change (IPCC) has defined our common agenda: accelerating scientific and economic research to help reduce remaining uncertainties; taking action now that responds to our present state of knowledge; and negotiating a multilateral framework for comprehensive response strategies.

Through our U.S. Global Change Research Program, we are working aggressively with other nations to improve our understanding of the global ecosystem and the relationship of our economic activities to the natural environment. We look forward to continuing this partnership.

In addition, a number of nations are implementing policies to reduce greenhouse gas emissions. I am pleased to provide a copy of the U.S. action plan for climate change - America's Climate Change Strategy. This comprehensive strategy for action is built upon a series of actions ~~which will have broad-ranging benefits~~ - from curbing air pollution, to conserving energy, to restoring forest lands - and which will help curb net greenhouse gas emissions. *taken to address a number of environmental concerns*

In total, the actions which are currently included in America's Climate Change Strategy will result in U.S. greenhouse gas emissions in the year 2000 being equal to or below the 1987 level. I hope that the results of our efforts here will be structured in such a way as to encourage such national strategies -- and to avoid any incentives to delay taking those actions which clearly have merit.

We in the U.S. take the challenge of global stewardship very seriously and feel that these negotiations offer the opportunity to structure an important vehicle for cooperation toward that end. The outcome of our talks will be profoundly important -- and working together, I am sure that we will be successful.

DRAFT / 2-3-91 6:30pm

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

Distinguished delegates, representatives of the nongovernmental community, members of the press, 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 venue under the auspices of the United Nations General Assembly to begin discussions on an issue of the utmost importance.

President Bush sends his personal greetings to each and every one 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.

Lest there be any doubts about the United States' outlook as we enter these negotiations, let me state it clearly:

- o First, we recognize the growing scientific consensus that continued loading of the atmosphere with greenhouse gases will lead to global climate change. Uncertainties do remain as to the rate, magnitude, and geographical characteristics

of such change. But we do not question the basic source of concern.

- 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 that the U.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. As our scientific and economic knowledge advances in the future, I am confident that the United States will continue to exercise leadership in responding to that information.

- 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 these negotiations 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 inflicts enormous damage on the planet we seek to protect. Just last week, the Environment Ministers of the OECD countries joined in the condemnation of this despicable crime.

Saddam's unconscionable act will 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 avoid focusing only on narrow aspects of a complex problem. Twenty years ago, when we in the United States enacted our first environmental statutes, we made that mistake. The Clean Air Act of 1970... the Clean Water Act

of 1972... the Toxic Substances Control Act... the Resource Conservation and Recovery Act... Too often, these statutes moved pollution around from air to land to water. We achieved substantial success in cleaning up our environment, but there is a better approach. The environment is holistic-- a dynamic system of interactions between living things, the waters, land, and skies. As we consider climate change, we should agree to address the total and cumulative effect of all greenhouse gas sources and all sinks.

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." This means we must be as sensitive to social ecology as we are to the natural ecology.

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. Those of us fortunate enough to enjoy an advanced state of development must work with our neighbors to help them avoid the mistakes we made as we developed. 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. The progress of research, the progress of diplomacy, and the progress of action.... 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.

Welcome to the United States. We hope you will enjoy your stay and I look forward to meeting many of you over the course of these discussions.

Thank you.

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THE WHITE HOUSE

WASHINGTON

January 23, 1991

MEMORANDUM FOR THE DOMESTIC POLICY COUNCIL

FROM:

RICHARD W. PORTER 
Executive Secretary

SUBJECT:

Framework Convention on Climate Change

An options paper on questions relating to the negotiations for a framework convention on global change is attached. The paper has been prepared for the DPC by the Global Change Working Group chaired by Dr. Allan Bromley, Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy.

Due to time constraints, I am circulating this paper for your consideration in lieu of the usual meeting of DPC principals. By 9:00 a.m. Thursday, January 24, please provide: (1) the response you would recommend to each of the three questions; and (2) your comments and clearance on Appendix B (a document proposed for release at the first negotiating session outlining U.S. accomplishments relating to climate change).

I apologize for the short turn around, but it is dictated by several factors including the printer's deadline. Thank you for your cooperation under these circumstances.

Responses should be sent (Room 231, OEOB) or faxed (456-2223) to me.

Attachment

THE WHITE HOUSE

WASHINGTON

January 22, 1991

MEMORANDUM FOR THE DOMESTIC POLICY COUNCIL

FROM: The Global Change Working Group

SUBJECT: Framework Convention on Climate Change

ISSUE:

Negotiators representing the United States at the first negotiating session of the Framework Convention on Climate Change on February 4, 1991 require guidance on three issues:

- (1) Aspects of the strategy U.S. representatives should follow during the negotiations;
- (2) Whether we should press other nations to adopt the "comprehensive approach;" and
- (3) Whether a document outlining U.S. accomplishments should be released at the first negotiating session.

BACKGROUND:

1. The General Situation.

Formal negotiations on a framework convention will take place, over the next 18 months, under the auspices of the United Nations General Assembly. Although differences exist regarding the purpose of the Convention, it is our understanding that the Convention should establish an institutional basis for international cooperation on climate change including the conduct of scientific research and the exchange of climate change information. It will also provide the legal and logistical structure for future protocols or annexes (if any) containing specific commitments. The Convention is expected to be ready for signing at the June 1992 U.N. Conference on Environment and Development in Brazil.

President Bush has invited other nations to meet in Washington for the first negotiating session. This is scheduled to take place February 4 to 14, 1991. The first negotiating session will focus on organizational and procedural issues. This paper provides background on the question of climate change and addresses three issues that need to be considered prior to the negotiations.

2. Previous International Action.

The World Meteorological Organization and the United Nations Environment Programme set up the Intergovernmental Panel on

Climate Change (IPCC) in 1987 as a vehicle to assess scientific information pertaining to climate change, impacts of such change, and possible strategies to assist in responding to potential changes. The U.S. participated in and accepted the activities of the IPCC.

At the Second World Climate Conference in November 1990, the IPCC adopted an interim report. This report addressed 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. This report forms the basis for the negotiations.

The Second World Climate Conference agreed that the scientific conclusions set out by the IPCC reflect the international consensus of scientific understanding of climate change, including these key points:

- o "Emissions resulting from human activities are substantially increasing atmospheric concentrations of greenhouse gases. These increases will enhance the natural greenhouse effect, resulting on average in an additional warming of the Earth's surface."
- o "Without actions to reduce emissions, global warming is predicted to reach 2 to 5 degrees C over the next century, a rate of change unprecedented in the past 10,000 years."
- o "The warming is expected to be accompanied by a sea level rise of 65 cm (+/- 35 cm) by the end of the next century."
- o Substantial scientific uncertainty continues regarding the details of climate change. To narrow the uncertainties, on-going research is being conducted in high priority areas, such as oceans, clouds, carbon cycle, polar ice sheet, and sea ice.

Some policy makers do not share the certainty reflected by the predictions published in the IPCC report, because of the unsettled state of the scientific analysis.

3. The Science of Climate Change.

Studies show that concentrations of greenhouse gases have increased. However, the causes of this increase--including both natural and human factors, as well as the way these may affect regional climate patterns and the earth's temperature regulation process--continue to be unclear. Certain gases, such as carbon

dioxide, methane, nitrous oxide, and chlorofluorocarbons (CFC's), increase the retention of heat in the atmosphere.

Natural processes are responsible for twenty times the amount of greenhouse gas fluctuations than those caused by human activities. For instance, even though nitrous oxide is emitted by the man-made process of burning fossil fuels and using nitrogen fertilizers, it is also emitted by the natural aerobic decomposition of organic matter in oceans and soils and by bacteria. Nevertheless, significant changes in atmospheric concentrations are being caused by human-related activities, largely reflecting increases in industrialization.

The earth adapts to changes in greenhouse gas concentrations through a complex system that naturally regulates global temperatures. One result of this natural regulatory process may be changing climate patterns and higher average temperatures. This system is not only affected by "sources" of greenhouse gas emissions, but also by "sinks" that sequester concentrations of these gases. The system also includes the radiation of energy into space.

Although scientific research on the relation between the emission of greenhouse gases and climate change has focussed on global warming, this is only one of several interrelated climate phenomena that may be affected by such emissions. Other climate phenomena that may be affected include the patterns and amounts of precipitation, the patterns and severity of storms, as well as the mean sea level. Each of these climate phenomena may involve significant fluctuations in temperature over wide regions of the earth's surface. It is important to note that the effects of climate change may vary by region. Changes in temperature and precipitation may cause adverse effects in some areas of the world while resulting in beneficial effects in other areas.

Computer models have been developed to predict the effects on climate of different concentrations of greenhouse gases. Nevertheless, these computer models are not yet able to reflect the natural system of temperature regulation with much accuracy. As a result, scientists are not able to agree on the magnitude, spatial distribution, and timing of any climate changes caused by increased concentrations of greenhouse gases and the effect of natural mitigating factors. The computer models are particularly poor guides to regional variations of climate changes. These changes are the basis upon which economic impact studies are made, and are key to the development of responsible policy decisions.

4. The Economics of Climate Change.

Cost-benefit analyses of proposals for reducing emissions compare the costs of such proposals with any benefits they would produce

by altering climate processes. These benefits would equal the total costs of projected climate changes (often called the costs of not acting) only for proposals that promise to stabilize the climate. Most emission limitations that have been proposed internationally would reduce natural and human emissions only slightly and would therefore have only a minor effect on climate processes.

Economic studies of climate change issues have only just begun and little is yet known. For example, there are few quantitative analyses of the cost of sea level rise. Nor has there been much study of the impact that future climate changes may have on the agriculture, forestry and fishing industries, which are sensitive to climate variations. These industries amount to only 3 percent of the U.S. GNP, but they represent a much larger part of the economies of developing nations.

Studies based on historical data regarding carbon dioxide emissions suggest that stabilization or small reductions would impose costs on the order of 1 percent of GNP for industrialized countries by the turn of the century and that those costs would rise over time. Other studies based on analyses of particular technologies suggest that, in principle at least, costs could be more modest. Advances in technology could lower baseline emissions, costs of reduction, and the tendency of costs to rise over time.

5. Energy Issues in Climate Change.

Even though human activities cause only a fraction of greenhouse gas emissions, international talks have focused on reducing man-made emissions, especially emissions from the use of fossil fuel. The U.S. produced almost 6 billion tons of carbon dioxide from fossil fuels in 1988. Because this was about 25 percent of all man-made carbon dioxide emissions world-wide, the U.S. has become a large target for criticism from other countries despite our positive record on overall greenhouse gas emission control. It is worth noting that the U.S. also produces about 25 percent of the world's GNP, so that its share of man-made carbon dioxide emissions compares with its share of production.

THE CLIMATE CONVENTION NEGOTIATIONS:

A framework convention establishes general obligations and procedures for carrying out these obligations. Specific commitments are usually included in subsequent annexes or protocols to a convention. Nevertheless, several countries are pressing to include specific obligations for targets and timetables for stabilizing emissions of certain gases in the convention or in protocols negotiated simultaneously with the convention.

We have taken the position that such commitments are premature and should be negotiated, if at all, only after signing a framework convention. Even then commitments should be made only if analyses demonstrate that they are necessary and will result in net benefits. The model is the Vienna Convention (March 22, 1985) on ozone depletion and the subsequent Montreal Protocol (September 16, 1987). We are uncertain of the level of support the U.S. will receive on our position and may have to reconsider if other countries fail to support us.

1. The Process.

The climate change negotiations will be carried out through the auspices of the Intergovernmental Negotiating Committee, serviced by a United Nations Secretariat. Following the first session here in Washington, most of the negotiating sessions will be held at U.N. facilities in Geneva, with one or possibly more sessions in Nairobi. Sessions will be one to two weeks in length, and will be held every three or four months through 1991. Sessions will be scheduled as needed in 1992. Jean Ripert of France is likely to be elected to chair the negotiations.

2. The 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 energy, environmental, scientific and economic expertise and interest in this issue. Federal government agency involvement with the framework convention is being coordinated by the Department of State. White House coordination of the negotiations is being provided by the Office of Science and Technology Policy.

3. Agenda for the First Session.

Although a draft agenda has not yet been circulated by the U.N. Secretariat, the following work-plan is anticipated for the nine-day session:

- o Organizational matters (1 day);
- o Initial country statements (2 days);
- o Establishment of subgroups and preparation of the legal negotiating text (5 days); and
- o Other matters such as defining the relationship between the IPCC and these talks (1 day).

Countries will propose text they wish to see included in the convention. Language not agreed to by all the parties will be bracketed. Little attempt will be made to resolve differences about the text during the first session.

The U.S. will propose several non-controversial provisions, particularly in the area of scientific and economic research and cooperation. More importantly, as discussed in question 2 below, the U.S. will seek to convince other countries that they should adopt the comprehensive approach in the text of the framework agreement.

A summary of other countries' positions on the global change issue and their approach to the framework convention negotiations is attached in Appendix A.

4. Elements for Possible Inclusion in the Framework Convention.

In addition to certain non-controversial elements of the framework convention identified by the IPCC, we expect several controversial elements to be proposed as well.

-- Targets and Timetables: Several countries will try to force a debate about targets and timetables for reductions of greenhouse gas emissions, particularly carbon dioxide emissions from the burning of fossil fuels, over the next 18 months. All other OECD countries, except Turkey, have made statements arguing that such obligations should be undertaken now, either as part of the convention itself or in protocols negotiated simultaneously with the convention.

-- The Precautionary Principle: Many countries will suggest putting an article on the "Precautionary Principle" into the framework convention. As yet, there is no commonly accepted definition of this principle. Some believe it merely reiterates the need to prevent pollution. Others hold that it imposes a burden of proof, i.e., that an activity cannot be undertaken unless proof can be shown that it will not harm the environment.

-- Financial assistance: Consistent with the Houston Economic Declaration, a general commitment to promote financial assistance for developing countries will be negotiated 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 will argue that the newly established Global Environmental Facility 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, there is a wide range of technologies for which this issue does not arise. U.S. negotiators intend to highlight the value of existing cooperation programs.

QUESTION 1: Should the following strategy be adopted to guide U.S. representatives at the first negotiation session?

1. Propose specific language on scientific cooperation and monitoring consistent with the comprehensive approach.
2. Oppose specific targets and timetables for greenhouse gas emission reduction--particularly carbon dioxide.
3. Oppose extreme statements of the "Precautionary Principle."
4. Oppose commitment to new and additional financial assistance.
5. Explore ways of promoting technology transfer that will be advantageous to the U.S., taking full account of market forces and the protection of intellectual property rights.
6. Highlight steps already taken to show U.S. commitment to act. (See Question 3 for further elaboration).

Over the past year, the U.S. has taken a prudent approach to the climate change issue. Other countries have been willing to commit themselves to specific targets and timetables for reducing greenhouse gas emissions with little regard, in some cases, for either the cost or the lack of information necessary to craft an effective plan.

The U.S. is widely perceived as entering these negotiations in an isolated position, since it is the only major developed country that has not committed itself to a timetable for achieving specific greenhouse gas reductions. Therefore, to buttress the prudence of our approach we will need to have a well-defined negotiating plan to take with us to the table in February.

The U.S. can bolster its position on targets and timetables by pointing out the scientific uncertainties as well as the likely costs, administrative complexities, and possible trade problems that could arise from the imposition of large taxes on the carbon content of fossil fuels--the primary means for achieving major reductions. We have solid economic and scientific research already under way and partially completed that could be used to back up this position.

To address the doubt expressed by other countries concerning the sincerity of our commitment on the climate change issue, we may wish to consider signals that would show the U.S. commitment to act. Indeed, we are already taking steps--albeit steps justified for other reasons such as energy security, clean air and other

environmental concerns--that address climate issues and that can be used to improve the U.S. bargaining position. (Question 3 sets forth a specific proposal in this regard).

Pros:

- o This strategy highlights steps already taken that demonstrate U.S. leadership, and underscores the prudence of the U.S. approach for addressing global climate change.
- o The positions outlined are consistent with past U.S. negotiations on the issue.
- o The strategy emphasizes the importance of reliable scientific and economic research as the basis of any action.
- o Avoiding specific commitments on timetables and levels of reduction until subsequent protocols provides more time to gather the scientific and economic data necessary to make informed decisions.
- o The approach is supported by some other countries (including Canada and some developing countries) and by some environmental leaders.

Cons:

- o This strategy may be considered a delaying tactic by other countries, by environmental groups and by the media.
- o If our position is seen as too obstructionist, it may reduce our negotiating leverage on this issue.
- o The media is likely to continue its criticism of the Administration on this issue.

QUESTION 2: Should U.S. negotiators press other nations to adopt the "comprehensive approach" in the Framework Convention?

Over the past year, the U.S. has actively promoted a "comprehensive approach" to greenhouse gases. Under this approach, all gases would be placed on an equal footing based on a scientifically determined "greenhouse potential index"--an index taking into account the intrinsic molecular greenhouse efficiency of each gas, its average residence time in the atmosphere and other relevant considerations.

This approach is preferable because: (1) other gases than carbon dioxide are greenhouse gases, some of which are less costly to

regulate (such as CFC's); (2) it would ensure that developing nations contribute to the international effort; (3) it lays the groundwork for a market approach (nationally and internationally) to reduce emissions at the lowest possible cost; (4) it avoids problems inherent in attempting to develop individual protocols for each greenhouse gas, and (5) it focuses attention on the potential for expanding sinks that sequester greenhouse gas emissions.

Pros:

- o Promotes an innovative approach to the issue of climate change enhances U.S. leadership in the negotiations.
- o Moves the climate change issue away from a narrow focus on carbon dioxide which places a disproportionate burden on energy and transportation sectors of the economy.
- o It is a more valid approach, from a scientific perspective, than other approaches.
- o Focussing on the total picture, including both sinks and sources, increases the flexibility of efforts to limit the effects of greenhouse gases.

Cons:

- o Some countries may portray our strong support for this approach as a ploy for avoiding the reduction of carbon dioxide.
- o May involve measurement requirements too sophisticated for some countries to handle.
- o Scientific uncertainties regarding characteristics and behavior of some of the gases make it difficult to calculate exactly comparable indices at this time.
- o Methods for monitoring and reducing emissions of greenhouse gases from sources such as forestry, bovine animals, and pipelines are still being developed.
- o May become a tactical bargaining chip that could be used to pressure the U.S. into accepting targets and timetables.

QUESTION 3: Should a document be released at the first negotiating session outlining U.S. accomplishments that reduce greenhouse gas emissions?

Although we have opposed specific timetables and targets for reducing emissions, the U.S. has already taken steps that address

the possibility of global climate change, such as the global change research program, the Clean Air Act, phasing out CFC's, and the tree initiative. In fact our efforts are unmatched by any other country. Nevertheless, the U.S. was portrayed as anti-environment at earlier climate change conferences principally because of our lack, to date, of initiatives in the energy sector. This situation might change if attention is directed to our achievements. For this reason, we are developing a publication to highlight U.S. accomplishments which could be distributed at the first negotiating session.

The document could be framed as a U.S. "Action Plan" on climate change. While it would be comprised of steps already approved or on their way to being implemented, it is important not to frame the document solely as an "accomplishments" brochure, lest there be an attempt to discount actions already taken in order to press for future commitments. Similar brochures have been prepared and distributed by other countries at past conferences. A draft for such a document is attached in Appendix B.

Pros:

- o The concrete steps taken by the U.S. compare well with the largely rhetorical policy pursued by critics of the Administration.
- o A quality document would demonstrate our rigorous interest in the global climate change issue without breaking new policy ground.
- o The U.S. would no longer be the only country without an "Action Plan."

Cons:

- o Could become the focus of a negative campaign by being portrayed as papering over the U.S. unwillingness to make new international commitments.
- o May raise questions about why the U.S. still refuses to endorse targets and timetables--if the U.S. is so close to achieving targets others only talk about, why does it continue to resist targets?
- o Could provide fodder for manipulation by countries or interest groups with opposing views of the United States.

Attachments

Country Targets and Timetables

Australia

Cabinet announced target 11 October of stabilizing CO₂, CH₄, N₂O at 1988 levels by 2000, reducing 20 percent by 2005, provided no net adverse effect on Australian competitiveness if other major developed nations do not take similar actions.

Austria

Urged at February IPCC plenary that industrialized countries stabilize by 2000 as first step; no specific domestic target set.

Belgium

Said at IEA meeting in July that it had begun taking actions that would lower emissions, but had not yet conducted the analysis necessary to justify establishing a target. Supported US position at Bergen.

Brazil

President Collor noted in June World Environment Day speech the need for specific commitments for the stabilization and reductions of CO₂ emissions per capita. He implied, but did not explicitly state, that he was referring foremost to the fossil fuel emissions of developed countries.

Canada

Pledged in June to stabilize CO₂ at 1988 levels by 2005.

China

Strongly implies that it favors targets for developed countries, opposes them for LDCs. Projects substantial CO₂ emissions growth.

Denmark

National energy plan calls for 20 percent CO₂ reduction by 2005.

EC Commission

Favors stabilization of CO₂ at 1990 levels by year 2000, significant reduction by 2005.

Finland

Urged at IPCC February plenary that industrialized countries stabilize by year 2000 as first step, no specific domestic target set.

France

Proposed in September a three-tiered global strategy to converge per capita CO2 emissions rates by early 21st century. Under this plan, France would stabilize its emissions at or below 2.0 tons per capita by 2000 (up to a 10 percent increase from current levels), provided that other major industrialized countries agree to stabilize their emissions.

Germany

Cabinet announced in June non-binding commitment to reduce CO2 emissions 25 percent from 1987 levels in former West German area by 2005.

India

Opposes targets for developing countries.

Israel

Opposes targets.

Italy

Supports stabilization of CO2 at 1990 levels by 2000 as part of EC-wide initiative. No domestic target set.

Japan

Announced action plan 19 October to stabilize CO2 emissions per capita at 1990 levels by 2000. Methane emissions will also be capped at current levels. Gross CO2, N2O, and other greenhouse gas emissions will be stabilized by 2000 if feasible.

Malta

Supports targets and timetables; no domestic target set.

Mexico

Appreciates unilateral commitments by industrialized countries to stabilize emissions by 2000. Believes obligations should be equitably differentiated according to

countries' respective responsibilities for causing and combatting climate change and their level of development.

Netherlands

Parliament passed in September revised National Environmental Policy Plan, calling for stabilization of CO2 emissions at 1989-90 average by 1994-95, 3 to 5 percent reduction by 2000. Government officials describe commitment as binding.

New Zealand

Environment minister announced plans in September to reduce CO2 emissions 20 percent from 1990 levels by 2005.

Norway

National goal is stabilization at 1987 levels by 2000, provided other countries take similar actions.

Portugal

Opposes targets.

Saudi Arabia

Favors stabilization by 2000 target for industrialized countries; no domestic target set.

Spain

Would support EC stabilization target if scaled to current per capita emissions so as to be equitable among EC members.

Sweden

Parliamentary mandate to stabilize CO2 at 1988 levels. Supported call at IPCC February plenary for stabilization by 2000.

Switzerland

Urged at IPCC February plenary that industrialized countries stabilize emissions by year 2000 as first step; no domestic target set.

United Kingdom

Prime Minister Thatcher announced in May that the UK would enact a strategy to achieve a stabilization of CO2 emissions at 1990 levels by 2005, provided other major industrialized countries take similar steps.

USSR

Opposes targets.

Venezuela

Opposes targets.

Note: Only the government of the Netherlands describes its target as binding.

America's Climate Change Strategy



An Action Agenda

LEADERSHIP AND ACTION

President Bush has established the comprehensive strategy for action and leadership outlined on the following pages. This strategy flows from his commitment to economic growth and to responsible stewardship of our planet. It is built upon a series of actions which will have broad ranging benefits — from curbing air pollution, to conserving energy, to restoring forest lands — and which will help curb greenhouse gas emissions.

The U.S. believes that any successful global climate change strategy must be:

- **comprehensive**, incorporating all relevant greenhouse gases, their sources and sinks;
- **long term**, taking into account the full range of social, economic, and environmental consequences of proposed actions for this and future generations;
- **flexible**, built on many diverse actions (including market incentives) and readily adjustable as knowledge is improved through a robust research and development program; and
- **integrated**, designed to involve all nations and dynamically reflect and incorporate each nation's unique circumstances into the development of a truly global response strategy.

The actions which are currently included in the U.S. Climate Change Strategy will result in U.S. greenhouse gas emissions in the year 2000 being equal to or below the 1987 level. In addition, the U. S. has essentially stabilized its emissions of carbon dioxide (CO₂) over the last 15 years despite a growth in economic output of about 50 percent. During this same period, global carbon dioxide emissions have increased substantially.

This U.S. Strategy for Climate Change includes many specific actions:

- eliminating stratospheric ozone depleting compounds which are also strong greenhouse gases;
- increasing forest greenhouse gas sinks;
- directly controlling various greenhouse gases and their precursors which are also air pollutants;
- reducing utility and other industrial emissions in a way that strongly encourages energy efficiency;
- encouraging energy efficiency in such areas as buildings, appliances, and lighting; and
- increasing the use of renewable and non-fossil sources of energy.

Integral to the U.S. Climate Change Strategy is the world's largest program of research and development:

- to increase our scientific understanding of climate change and to provide a sound knowledge base for making major public decisions.
- to develop and to accelerate the adoption of economically sound,



environmentally beneficial, and energy efficient technologies.

In total, the U.S. proposes to invest over 2 billion dollars in these R & D efforts next year alone.

In August 1990, the Intergovernmental Panel on Climate Change (IPCC) stated in its Overview: "A comprehensive strategy addressing all aspects of the problem and reflecting environmental, economic, and social costs and benefits is necessary." The President of the United States has established such a comprehensive strategy. The United States, today, is working to curb emissions, promote economic growth, and exercise leadership in meeting our shared responsibilities as stewards of the planet.

The United States is taking action.

THE COMPREHENSIVE APPROACH TO CLIMATE CHANGE

The science and economics of human interactions with the global climate involve multiple trace gases affected by activities in every sector of human society. Each of these greenhouse gases is emitted from a variety of sources and is trapped or affected by "sinks" in different ways. Each gas has a different residence time in the atmosphere, a different ability to trap heat, and different potential impacts on the environment. What is important in addressing future climate change is the total and cumulative affect of all gases and all sinks.

In November, the government ministers at the Second World Climate Conference (SWCC) declared: "We recommend that in the elaboration of response strategies, over time, all greenhouse gases, sources, and sinks be considered in the most comprehensive manner possible ..."

The "Comprehensive Approach" has several advantages:

- It provides flexibility for each nation to develop a diverse, innovative, cost-effective mix of measures to meet its global responsibilities in a manner tailored to its own domestic circumstances; and
- It is designed to employ the results of integrated scientific and economics research on a comprehensive basis, using the results of our research investment to maximize benefits to the environment and humanity.

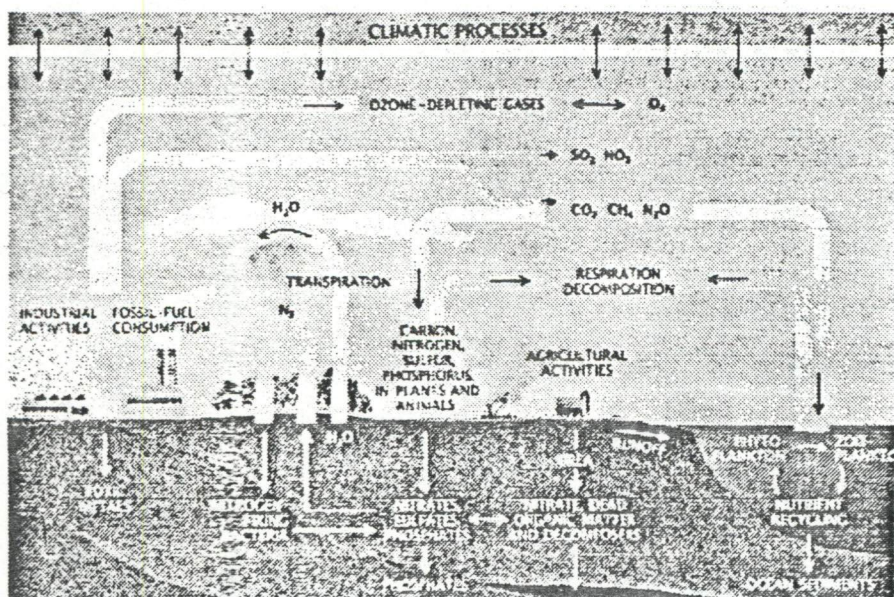
The relative benefit from a unit reduction in the net emissions of each greenhouse gas can be approximated by a measure of "global warming potential" based on the radiative behavior of the gas in the current atmosphere. The Intergovernmental Panel on Climate Change (IPCC) has calculated such a relative measure,

giving carbon dioxide a value of 1 and expressing all other gases in terms of carbon dioxide equivalents. This "index" enables a comparison of the contributions of different gases, their sources and sinks. (See chart opposite)

The costs of achieving a given reduction in the added greenhouse effect will vary from gas to gas and will vary depending on which sources or which sinks of any given gas are affected. Using the Comprehensive Approach, maximum reduction in net emissions or atmospheric concentrations can be achieved for any given level of investment.

If emissions limits were designed to apply piecemeal to one greenhouse gas or economic sector, economic actors could simply adjust to such narrowly focused regulation by shifting to unregulated activities that could continue to contribute to potential climate change.

A comprehensive approach, on the other hand, matches the scientific, economic, and environmental nature of the whole climate system.



THE BOTTOM LINE

Implementation of President's Comprehensive Climate Change Strategy will result in United States greenhouse gas emissions in the year 2000 being equal to or below 1987 levels.

The specific actions which will contribute to this result include:

- Phasing out CFCs and other ozone-depleting compounds which are also greenhouse gases.
- Putting a permanent ceiling on sulphur dioxide emissions, at sharply reduced levels and allowing freedom of choice in meeting the ceilings, thereby encouraging energy efficiency and reducing greenhouse gas emissions. Under the recently enacted Clean Air Act Amendments, utilities were given the flexibility to make reductions by any means — a powerful incentive for energy saving measures.
- Reducing, under the Clean Air Act, air pollutants which are either greenhouse gases themselves (nitrogen oxides) or greenhouse gas precursors (volatile organic compounds, carbon monoxide and nitrogen oxides).
- Initiating a program to plant a billion trees a year and to make other forest improvements. (Enhancing sinks)

- Implementing a number of programs aimed directly at speeding the adoption of energy efficient technologies and practices in homes and businesses.

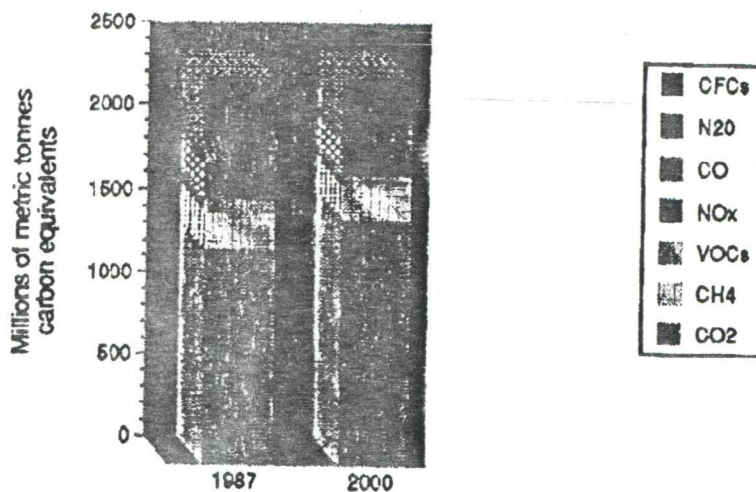
- Promoting the use of and accelerating research into non-fossil fuel energy sources, such as solar, nuclear, and alternative fuels.

The results of these currently planned U.S. actions are illustrated by Chart 1, which shows projected U. S. greenhouse gas emissions for the year 2000. The estimate is based on calculations made by the U.S. Environmental Protection Agency.

Chart 2 shows an alternative estimate based upon a different economic model prepared by researchers at Harvard University.

Projected U. S. Greenhouse Gas Emissions

(With Current Policy Commitments)
Based on IPCC CO2 Baseline Estimate



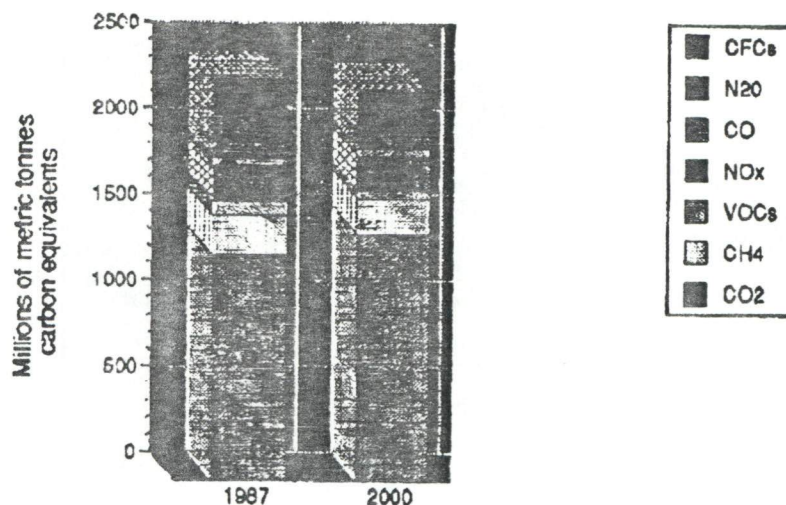
From EPA, "The Cost of Reducing Greenhouse Gas Emissions in the United States", Presentation by Alex Christofaro, Director, Air and Energy Policy Division, December 4, 1990

CHART 1

The actions which are currently included in the U.S. Climate Change Strategy will result in U.S. greenhouse gas emissions in the year 2000 being equal to or below the 1987 level.

Projected U. S. Greenhouse Gas Emissions

(With Current Policy Commitments)
Based on Jorgenson/Wilcoxon (1990) Model



From EPA, "The Cost of Reducing Greenhouse Gas Emissions in the United States", Presentation by Alex Christofaro, Director, Air and Energy Policy Division, December 4, 1990

CHART 2

PHASING OUT CFC's

The United States has long taken a leadership role in addressing the problem of stratospheric ozone depletion. In 1978 the U. S. banned the use of CFCs as propellants in spray can products. Such use was considered a low value use which could be forgone given the potential damage which it was believed that CFCs might be causing. All other countries, with one or two exceptions, continued to use CFCs as propellants.

At the London Meeting of Parties to the Montreal Protocol the U. S. supported a complete world-wide phase-out of CFCs, halons, and certain other ozone depleting substances such as carbon tetrachloride and methyl chloroform. The Protocol was amended to achieve that objective.

BEYOND THE MONTREAL PROTOCOL

The U. S. has enacted legislative provisions in the recent Clean Air Act amendments which will phase down U. S. production and consumption of these ozone depleting compounds more quickly than the amended Montreal Protocol provisions. (See charts opposite)

For each and every one of these compound groups and gases, the Clean Air Act reduces the allowed U. S. production and consumption between now and the final phase-out date substantially below what the Protocol permits. (For example, see chart — regarding CFC production)

Between now and the phase-out dates the U. S., under the mandates of the Clean Air Act, must reduce U.S. production below what is permitted by the Montreal Protocol by the following amounts:

"Cumulative Near-term reductions in Clean Air Act Below the Montreal Protocol"

Major CFCs	19%
Halons	32%
Other CFCs	22%
Carbon Tetrachloride	13%
Methyl Chloroform	20%

THE U.S. IS AHEAD OF SCHEDULE

In addition to the more restrictive phase-out schedules required by the Clean Air Act, the 1989

Reconciliation Act enacted a tax on ozone-depleting chemicals during the period of phase-out. The tax rates for each compound are its ozone depleting potential (ODP) multiplied by \$ 1.37 per pound in 1990 and 1991, \$ 1.67 in 1992, \$ 2.65 in 1993 and 1994, and an increase of an additional \$ 0.45 in each year after 1994.

This tax has already helped to reduce U. S. CFC production in the 12-month period ending June 30, 1990 to 23 % below the levels permitted by the Montreal Protocol and other U.S. law.

While these actions by the United States are justified by their benefits relating to stratospheric ozone depletion, they are also very highly significant for climate change. CFCs, halons, and carbon tetrachloride are extremely powerful greenhouse gases, thousands of times more powerful than carbon dioxide. Methyl chloroform is also a strong greenhouse gas that is in wide use. (See discussion of Comprehensive Approach above)

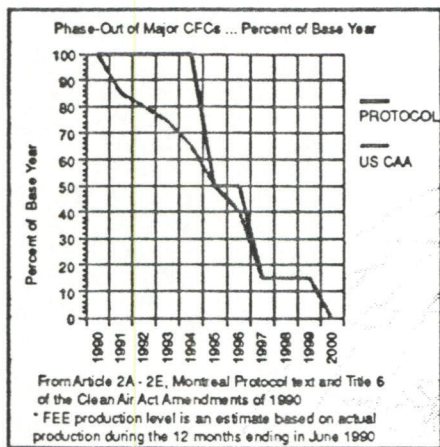


CHART 3

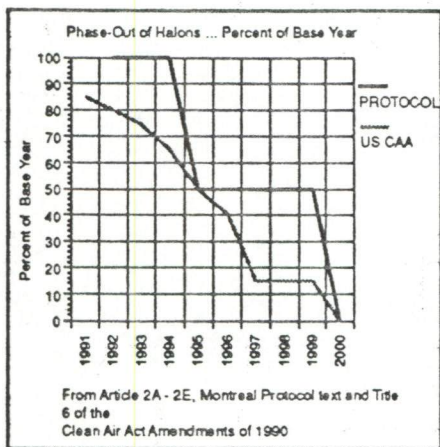


CHART 4

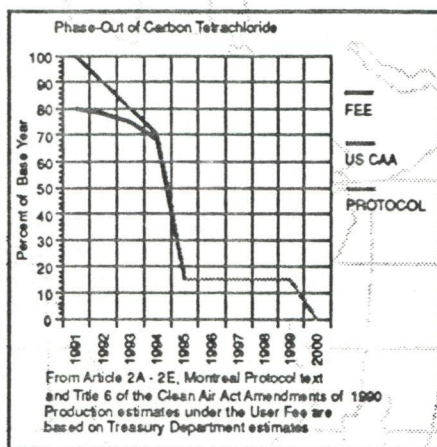


CHART 5

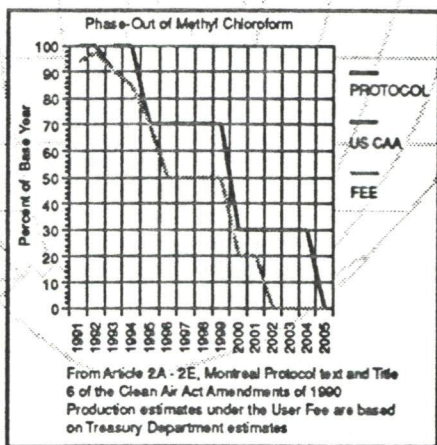


CHART 6

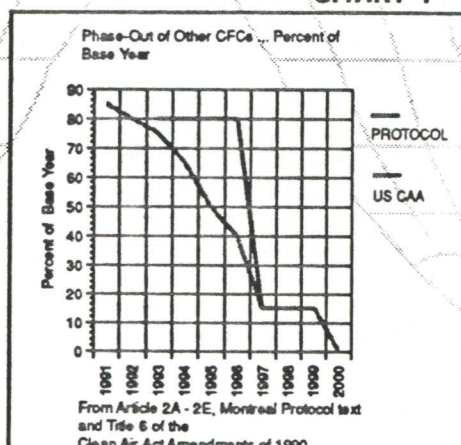


CHART 7

THE 1990 CLEAN AIR ACT AMENDMENTS

The 1990 Clean Air Act Amendments, signed by the President in November 1990, will achieve substantial reductions of greenhouse gases and their chemical precursors, such as volatile organic compounds, carbon monoxide, and nitrogen oxides, in addition to reducing emissions of the more familiar pollutants such as sulfur dioxide. Moreover, the Act will result in direct carbon dioxide reductions due to more efficient electricity generation. When converted into equivalent units of carbon emissions and taken together, these reductions will amount to a 16% decrease in greenhouse gases from these affected sources between the years 1987 and 2000.

The most dramatic reductions will come from electrical utilities. Under the Act, utilities, which must reduce sulfur dioxide (SO₂) emissions by 10 million tons below 1980 levels, are given flexibility to choose how to achieve these reductions. Utilities are thus free to choose cost-effective conservation measures to achieve compliance. This powerful conservation stimulus will sharply reduce carbon dioxide (CO₂) emissions from this sector.

Further, the Act requires utilities to reduce their nitrogen oxide emissions by two million tons under the acid rain provisions. These provisions also contain strong incentives for both electric utilities and industrial sources to adopt advanced, energy efficient technologies that will lower overall emissions, including carbon dioxide.

The Act is also expected to induce oil-burning utilities to switch to natural gas, which produces fewer greenhouse gases than does oil.

Substantial reductions in either greenhouse gases or their chemical precursors will also result from new controls on stationary and mobile sources mandated by the new Act in order to bring cities into attainment of national air quality standards. A wide variety of stationary sources of volatile organic compounds will be required to reduce emissions by adding controls or by changing production processes. Newly tightened automobile emission standards will further reduce emissions of hydrocarbons, carbon monoxide, and nitrogen oxides, and new controls on gasoline evaporation will greatly cut volatile organic emissions. In addition, gasoline itself will be reformulated to reduce its volatility, thus reducing volatile organic emissions at the source.

The Act will dramatically expand the introduction of clean-burning alternative fuels into the U.S. transportation sector. Several large states and the fleets of America's major cities are expected to introduce fuels and vehicle technology which will emit fewer greenhouse gases. Beginning in model year 1994, new tailpipe emissions standards for hydrocarbons, carbon monoxide, and nitrogen oxides will be phased in. Auto manufacturers will also have to reduce refueling emissions. Gasoline volatility will be

reduced and cleaner fuels will be required in the nine cities with the worst ozone problems and in 41 areas during the winter months when carbon monoxide standards are exceeded. A clean fuel car pilot program in California will use combinations of vehicle technology and cleaner fuels to meet tight standards. Twenty-six areas will have to limit emissions from centrally-fueled fleets of 10 or more vehicles.

Regulations are also being proposed under the new source performance standards of the Clean Air Act to require capture of pollutant gases which are given off by landfills. The purpose of the regulations is to capture air toxics and volatile organic compounds which are the chemical precursors of greenhouse gas ozone. Methane will also be captured and flared. Greenhouse gas emissions in the year 2000 will be reduced by an estimated 44 million tons of carbon equivalent.

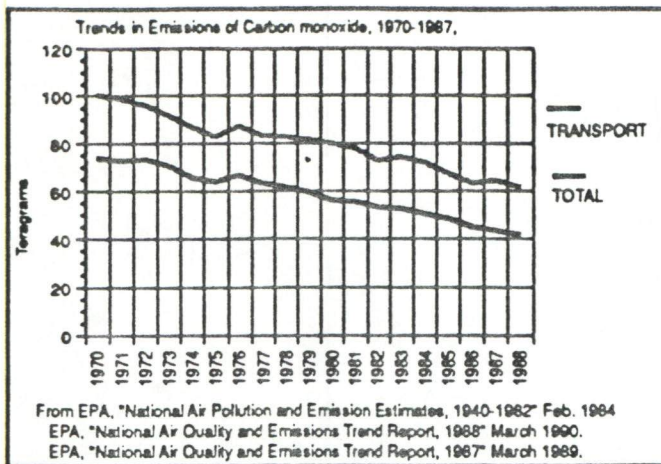


CHART 8

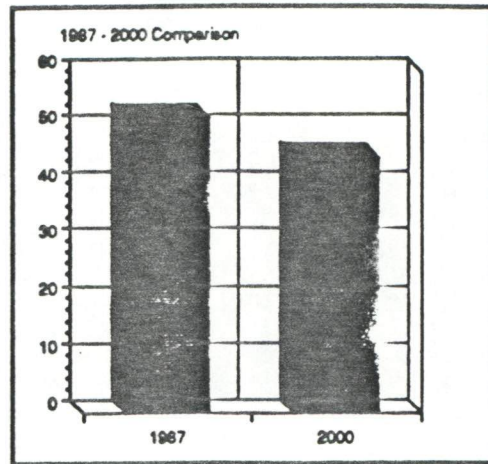


CHART 9

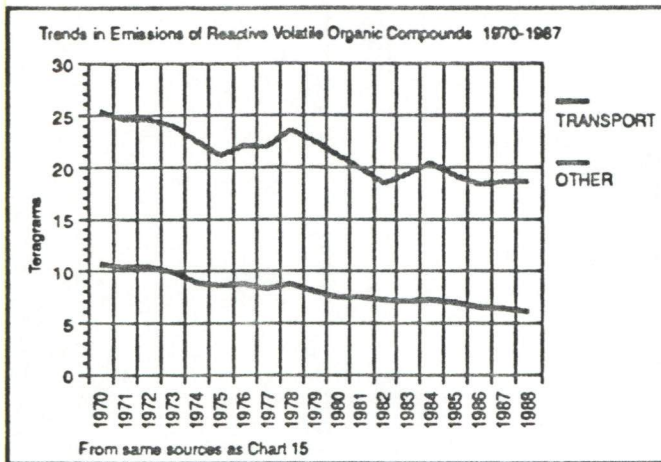


CHART 10

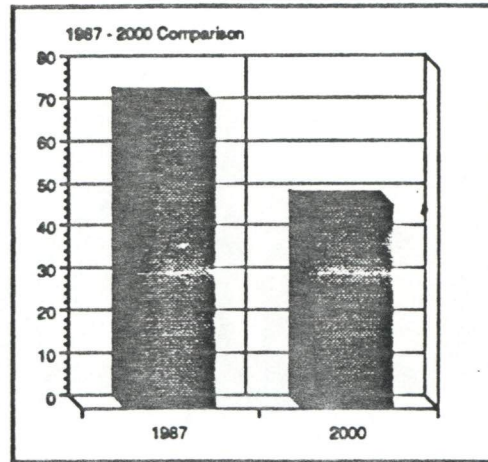


CHART 11

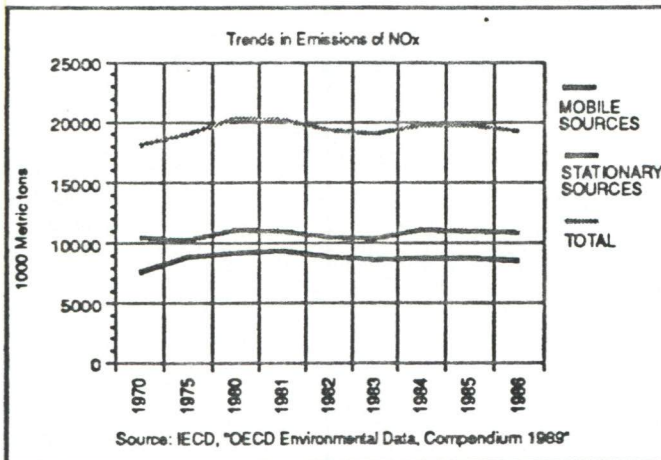


CHART 12

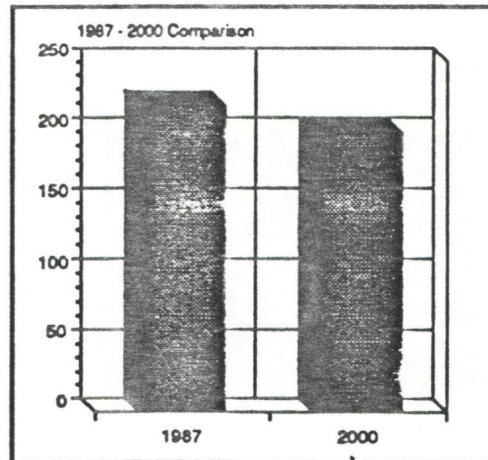


CHART 13

ENHANCING NATURAL SINKS

The term "sinks" of greenhouse gases is meant to include human and natural activities, processes, and phenomena that remove greenhouse gases from the atmosphere or reduce their atmospheric lifetimes. Examples include forests, soils and oceans. The IPCC recognized the importance of sinks in a report of its Response Strategies Work Group (RSWG): "The RSWG reviewed potential measures for mitigating climate change...These measures include those which limit emissions from greenhouse gas sources (such as energy production and use), those which increase the use of natural sinks (such as immature forests and other biomass) for sequestering greenhouse gases, as well as those measures aimed at protecting reservoirs such as existing forests."

Reforestation

The President has included in both his FY 1991 and FY 1992 Budgets a major, multiyear reforestation proposal to plant one billion trees per year on 1.5 million acres and to improve forest management practices on an additional 180,000 acres per year. This initiative will encompass cities and towns across America, as well as rural private, non-industrial forest lands. It comes in addition to reforestation which Federal agencies normally do on lands under their jurisdiction.

One purpose of this initiative is to improve the condition of private, non-industrial forest lands which are often now in poor condition due to low levels of management and investment. Improving these lands will increase benefits from soil protection, wildlife, wood products, and recreation.

This initiative will also have significant climate change benefits through the carbon which growing trees (sinks) remove from the air and store both as plant tissue and in the soil. The estimates of carbon removed from the atmosphere by the trees to be planted under the initiative are 9 million metric tons of carbon annually by the year 2000, growing to 50 million tons per year by 2010. (See chart 8)

Global Forest Convention

The President proposed at the Summit of Industrialized Nations in July 1990 at Houston to begin negotiations as expeditiously as possible on a global convention on forests, aiming for completion and signing by 1992.

The world's forests absorb carbon dioxide as well as provide many benefits in the form of timber and fiber, soil and water protection, wildlife habitat, recreation and other valuable outputs. They provide the habitat for some 80% of the planets remaining unknown and unspecified gene pool—a completely irreplaceable and potentially

enormously valuable heritage for all humankind. Temperate zone forests are being damaged by air pollution stresses and tropical forests are being rapidly lost.

The U.S. believes that the convention should emphasize market-based mechanisms and flexibility to achieve sound, sustainable forest use, to improve the health and vigor of forests, to encourage reforestation, and to increase the value of forests as sources of income and jobs.

Areas suggested for international cooperation and joint action include research and monitoring; education, training, and technical assistance; reforestation and rehabilitation; reform of the Tropical Forestry Action Plan; reduction of air pollution; bilateral and multilateral assistance; debt-for nature swaps; removal of harmful subsidies.

To put the power of trees as "sinks" into perspective, consider the example of an acre of improved stock of southern pine planted on a high quality site in the southeastern U. S. In the 15th year after planting these trees would take up between 5700 and 6200 pounds of carbon per acre. While the amount taken up declines thereafter as the trees mature, additional carbon continues to be taken up. (See chart 16)

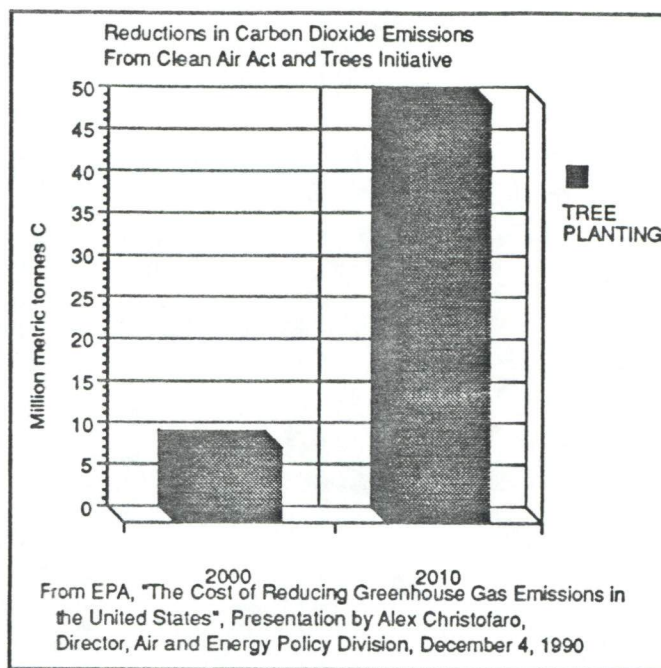


CHART 15

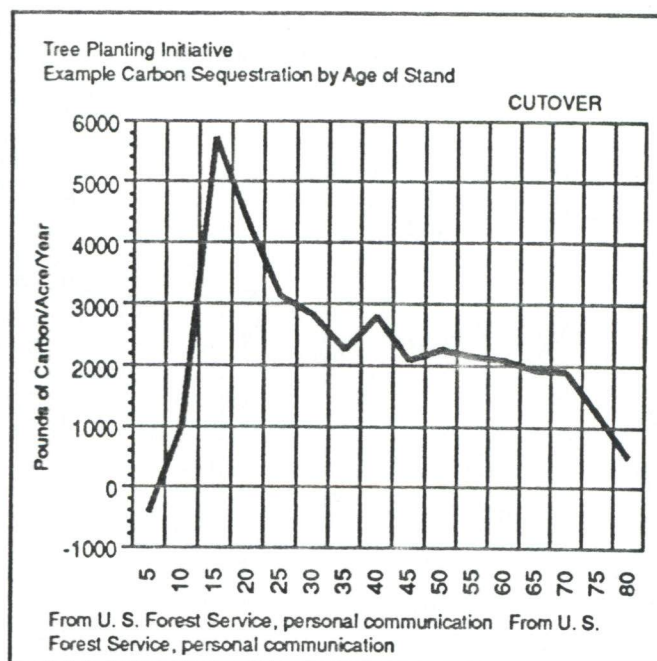


CHART 16

ENERGY INITIATIVES: *Efficiency*

The Administration is currently developing and will announce shortly a National Energy Strategy that will further contribute to the greenhouse gas emissions reductions cited here. Certain National Energy Strategy initiatives have been included in some of the calculations in this document.

The U.S. strategy for action includes a number of other energy efficiency measures, in addition to the Clean Air Act's strong incentives to save and use energy efficiently due to the utility emissions cap and the flexibility in complying given to utilities.

Level Playing Field Between Electricity Supply and Demand Reduction

In some cases utilities can meet demands for energy services without any additional greenhouse gas emissions by investing in energy efficiency rather than by increasing electricity supply. Utilities in only 15 states are now fully able to recover costs from such investments, including energy saving measures as well as new supply. Absent such efficiency measures, new capacity requirements by the year 2000 are projected at more than 100,000 MW.

The U.S. will work with the States to identify regulatory barriers that discourage utility investment in energy efficiency. Utility planning techniques will be developed to consider all alternatives and their costs. The U.S. will provide training, information dissemination, and other types of technology transfer activities. These actions will reduce greenhouse gas emissions in the year 2000 by 9 million metric tons carbon equivalent.

Encourage use of energy efficient building standards.

Both the U.S. and the private sector have developed standards that would achieve 20-25% energy savings in buildings. They could save \$5 billion over 20 years from the new buildings built in a single year.

The U.S. will promote voluntary use of these standards through training programs, design manuals and computer-aided design systems. It will encourage State and local governments to use the standards in their building codes. These actions to encourage adoption of the most energy efficient modern technology in residential and commercial building will reduce greenhouse gas emissions in 2000 by 8.2 million metric tons of carbon equivalent.

Use of the modern standard in public housing assistance programs will reduce greenhouse gas emissions by 800,000 metric tons carbon equivalent in 2000.

More efficient new appliance standards

Large appliances account for over two thirds of home energy usage, excluding space heating. In the past three years, the U.S. has imposed energy efficiency standards on many of the most energy-intensive appliances, including refrigerator/freezers, clothes washers, dryers, and dishwashers. These standards should achieve annual energy savings of 7-8% relative to projected use by the year 2000, and 14-15% relative to projected use by the year 2010.

The imposition of appliance standards has already resulted in a reduction of greenhouse gas emission. As older appliances are replaced with new, environmentally friendly models, the greenhouse gas reductions will increase dramatically. By the year 2000, DOE anticipates an annual reduction of 5.0 million tons of carbon equivalent from projected greenhouse gas emission due to these standards; the annual reduction will more than double to 10.6 million tons of carbon equivalent in 2010.

Expand national energy audit capabilities and use:

Industry, with some 350,000 separate establishments, uses 24.7 Quads of energy annually. Many options exist for low-cost quick payoff energy saving investments, but smaller firms often lack the information, expertise, and specialized resources to do energy audits of their plants.

The U.S. will increase its program to train engineers in energy audit and diagnostic methods from the current 13 engineering schools to 40 nationwide in the year 2000. This will reduce greenhouse gas emissions in the year 2000 by 6 million metric tons carbon equivalent.

More efficient lighting in federal facilities:

Twenty-five percent of federal agency energy use is for lighting of facilities. Budget constraints, lack of adequate information by facility managers, and restrictive procurement practices have slowed adoption of efficient new technologies.

The U.S. will identify energy savings options in Federal facilities. Project plans, procurement methods, and financing options will be developed to overcome the barriers to improve lighting efficiency. This will reduce greenhouse gases in the year 2000 by 1.4 million metric tons carbon equivalent.

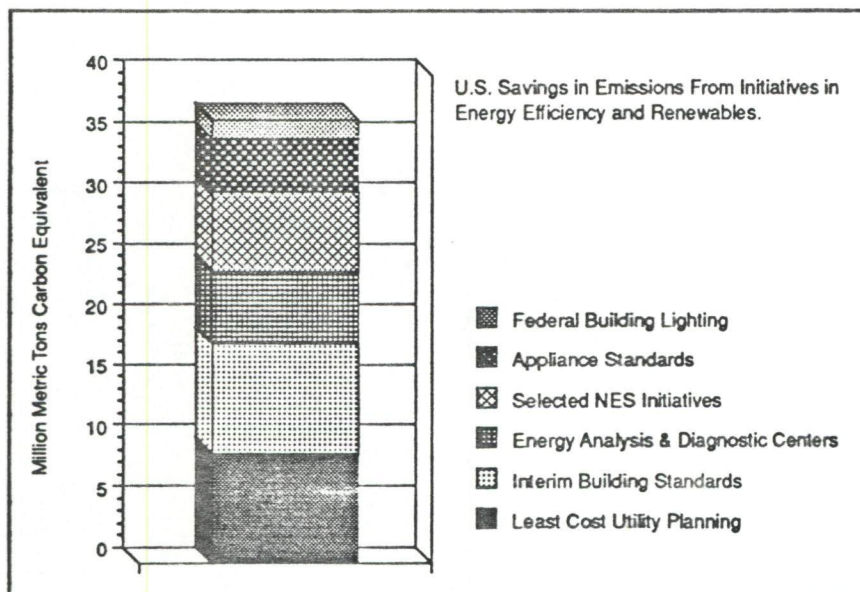


CHART 17

ENERGY INITIATIVES: *Renewables and Non-fossil Fuels*

Accelerate the transfer of photovoltaic technology to U.S. commercial production:

Recent laboratory research has achieved photovalic efficiencies of over 30%. With such efficiencies and improved manufacturing, today's \$4-5 prices per peak watt could be cut in half.

The U.S. will start an intensive effort with industry to understand potential improvements in photovoltaic processes. Industry joint ventures to provide practical solutions and maximize transfer of results will be encouraged. The U.S. will also provide cost-shared technical assistance to adapt manufacturing improvement techniques to specific processes. By the year 2000, greenhouse gas emission reductions will begin to phase in at 500,000 metric tons of carbon equivalent.

Expand nuclear energy capacity:

As the Nation enters the 1990s, nuclear power is the second largest source of U.S. electricity, providing almost 20 percent of America's electricity needs, and nuclear power causes no greenhouse gases.

Because of the availability of nuclear power the nation was able to avoid the use of large amounts of fossil fuels in 1989. In terms of the displacement of fossil fuels, nuclear power can take credit for reduced utility emissions of carbon dioxide—a major "greenhouse" gas—by 20 percent, or approximately 128 million tons. In overall terms, nuclear energy plants cut

U.S. emissions of carbon dioxide by nine percent. Worldwide, nuclear energy reduced these emissions by more than seven percent

A comprehensive strategy for nuclear energy is being developed as a part of the National Energy Strategy and is supported in the President's Fiscal Year 1992 budget. This strategy includes:

- Developing advanced light water reactors that will incorporate passive safety features in a standardized (modular) design. This will reduce the time needed to license new plants, while assuring that safety issues are adequately addressed. The U.S. is currently supporting first-of-a-kind engineering work that will assist companies in their efforts to have the Nuclear Regulatory Commission certify the safety of standardized designs.
- Conducting research and development on advanced reactor concepts with safety features that go beyond even the standardized designs ("to be intrinsically safe") currently before the Nuclear Regulatory Commission. High temperature gas cooled reactors use specially coated fuel elements that will not fail even under the high temperatures that could occur in an accident. Liquid metal reactors use liquid sodium as the heat exchange medium. Researchers have demonstrated that both reactor types can shut themselves down safely under conditions that would be extremely serious for present-day reactors.

- Reforming the nuclear licensing process through consolidation of the redundant aspects of the construction and operating licensing processes, without compromising nuclear safety concerns.
- Developing a long-term solution to the nuclear waste problem by developing a permanent repository, possibly an interim retrievable storage facility.

DOE is funding programs that are supporting growth in nuclear energy capacity and the life extension of many currently operating plants. According to analysis done for the National Energy Strategy, support from DOE is expected to result in adding new nuclear capacity by 2000 and to have On-line 264 GWe of new nuclear capacity, compared with 120 GWe today. Again, because nuclear power allows the nation to avoid the use of fossil fuels, such an expansion of nuclear use would result in yet a further substantial reduction in CO₂ emissions.

Increase transportation use of alternative fuels.

Use of oxygenated fuels, such as ethanol, can reduce urban smog levels, tropospheric ozone, and emissions of CO₂.

U.S. research has demonstrated the technical feasibility of the processes to produce ethanol from non-food domestic resources such as wood or herbaceous crops.

The U.S. will expand current research programs in alternative fuels to include cost-shared joint ventures aimed at reducing the cost of ethanol from non-food resource. This effort will be coordinated with industry vehicle and engine development programs.

ENERGY INITIATIVES: *Conservation and Renewable R&D*

The U.S. is funding a large research and development program for conservation and renewable energy. In Fiscal Year 1992 this effort is increased by 18 percent to a level of \$495 million.

In the long run, an adequate response to climate change will require the use of new technologies that conserve energy or that provide energy without causing greenhouse gas emissions. These technologies will be needed in all of the economy's sectors.

R&D for energy efficiency in transportation includes work on high temperature internal combustion engines, gas turbine engines, fuel cells and a new initiative for electric vehicles. Air transportation energy efficiency work includes research in hybrid laminar flow, composite materials, improved terminal operations, and improved air traffic control.

Alternative-fuel vehicle demonstration and a scale-up of a wood-to-ethanol process are being done. An initiative to address the problem of combustion emissions in waste-to-energy plants is being started.

Buildings energy efficiency research focuses on the interactions of energy systems, and the efficient use advanced window technologies and building materials to control light and heat entering a building.

Industrial energy efficiency R&D includes funding for more efficient steel, aluminum, and paper processes. A scale-up and test of the use of concentrated solar energy to detoxify liquid wastes will also be done.

The U.S. is proposing to initiate, in the fiscal year 1992 budget, a new joint auto industry—government consortium to develop a battery for electric vehicles. Improved batteries that could extend vehicle range to 120-200 miles could enable electric vehicles to capture as much as 20 percent of the market by 2030. Fuel-cell-powered electric vehicles offer the potential to achieve up to 50 percent efficiencies.

Total FY 1992 funding for research in new energy saving technologies is over \$900 million.

TRENDS: CO2 Emissions

U. S. emissions in 1988 were only 2.7 % above the 1973 level, despite the fact that real U. S. GDP, in 1985 dollars, grew by 48 percent over that period.

A key unanswered question about responding to the climate change issue is how to achieve economic growth in developing countries and economic reform in formerly centrally-planned countries without massive increases in greenhouse gas emissions.

Chart 22 compares the recent U. S. emissions trend with countries which contain most of the world's population, have trends of rapidly growing CO2 emissions, and are likely to have substantial emissions-generating economic growth in the coming decades.

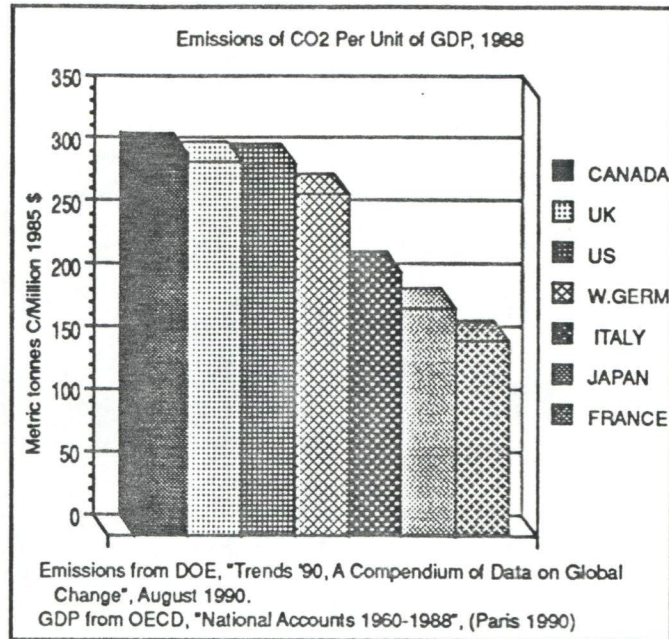


CHART 19

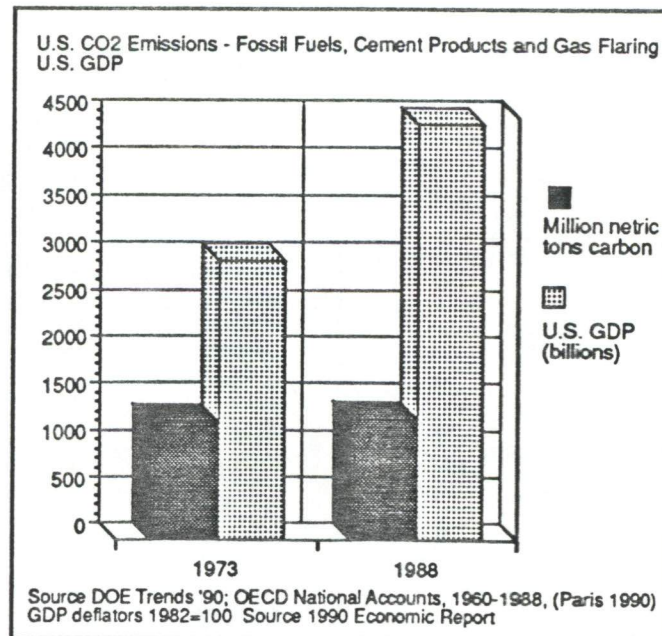


CHART 20

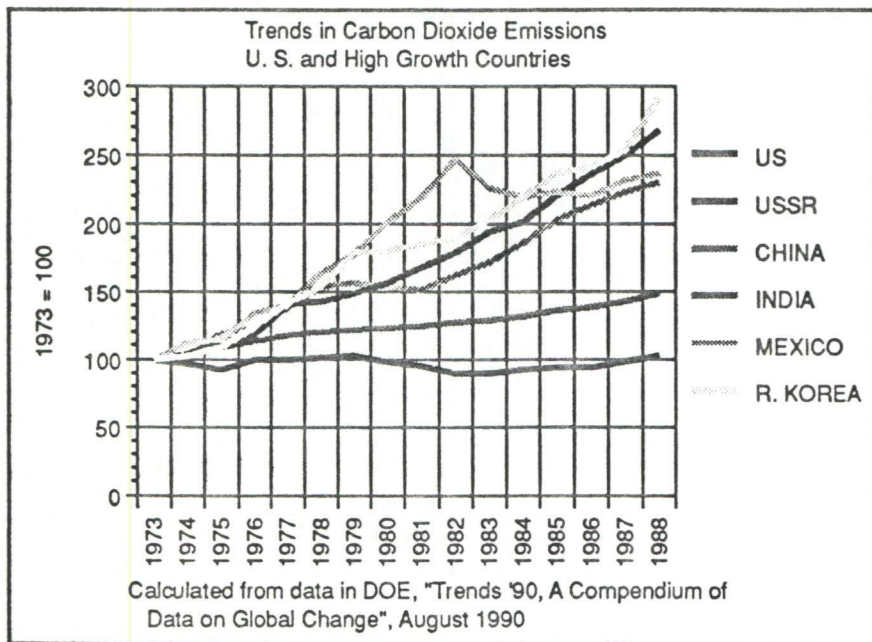


Chart 21 compares the U. S. trend to countries with substantial growth in emissions.

CHART 21

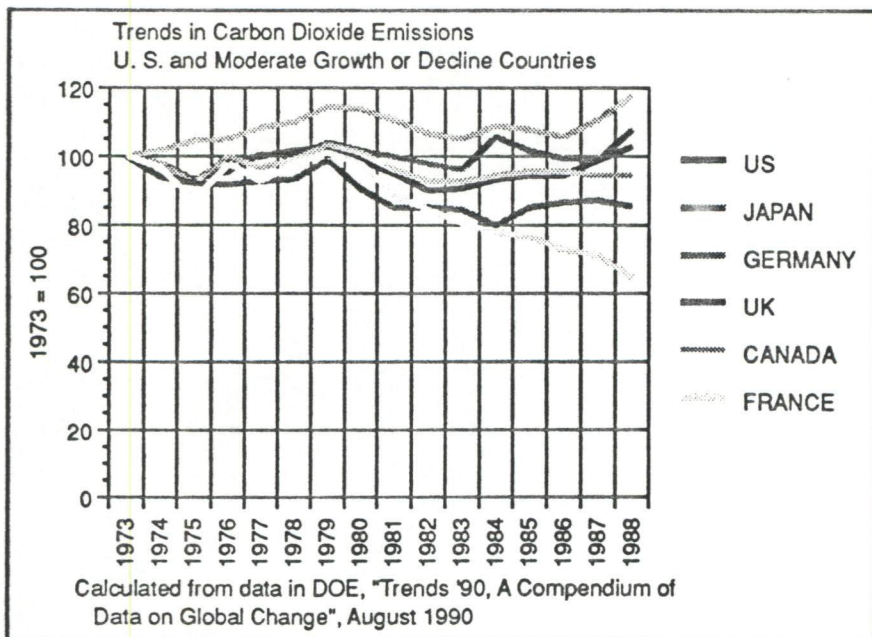


Chart 22 compares the U. S. trend to countries with moderate growth or decline in emissions.

CHART 22

TRENDS: Energy Intensity

Chart 23 compares United States energy consumption per unit of gross domestic product (GDP) with Canada, Japan, France, Italy, West Germany and the United Kingdom - the other G-7 countries.

However, as shown in Chart 24, the United States has improved its energy use/GDP ratio since 1970, averaging an annual improvement of 2 percent per year. In 1988 the U. S. used only 70.9 % as much energy per unit of GDP as it used in 1970.

The United States' rate of improvement in the industrial energy use/gross product originating (GPO) ratio has been greater than most other G-7 countries, averaging close to 3 percent per year since 1975 (Chart 24).

Since the early 1970s, the United States has improved its heating efficiency on an energy used per square foot per degree day basis. The U.S. used in 1987 only 68.4% of the energy used per square foot in 1972. Today, U.S. energy use in dwellings per square foot per degree day is much lower than most other G-7 countries.

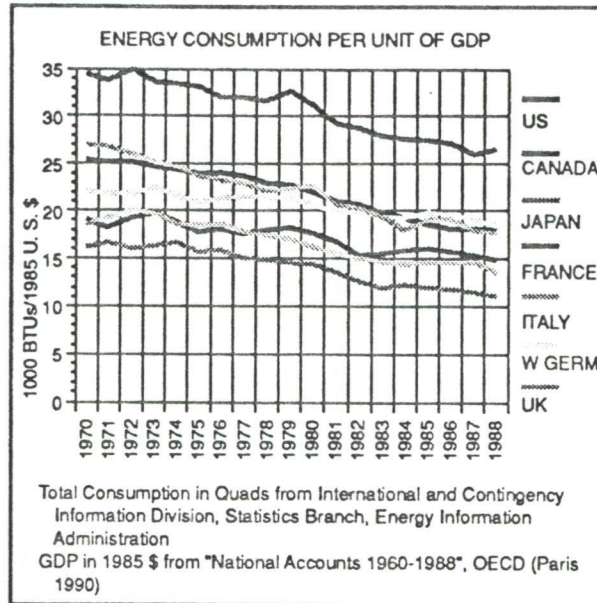


CHART 23

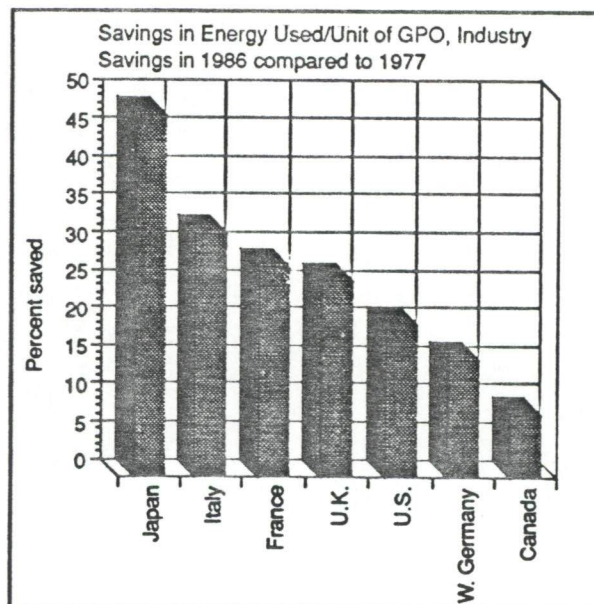


CHART 24

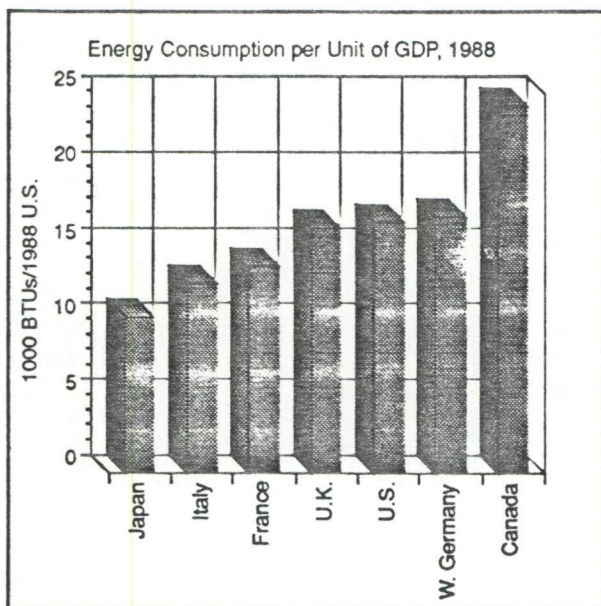


CHART 25

TRENDS: *Transportation*

Population density in the United States is 5 to 10 times less than in many of the other G-7 countries. With such a low density, the U. S. spatial spread between work and home often makes mass transit systems impractical. Distribution of economic activities across a wide continent requires substantial energy consumption for moving people and freight long distances. (chart 30) Transportation energy consumption per capita (Chart 24) is highest in the United States and Canada and substantially lower in the G-7 countries with high population densities.

New car fuel efficiencies in the United States are now roughly even with those of most of the other G-7 countries (Chart 25), despite much more demanding U. S. emissions and auto safety standards. The U. S. 1987 miles per gallon ratio was 28.3, within a relatively narrow range from Japan at 27.7 to the United Kingdom at 31.8. The U. S. from 1973 to 1987 increased its new car fuel economy by 100 percent. (chart 26)

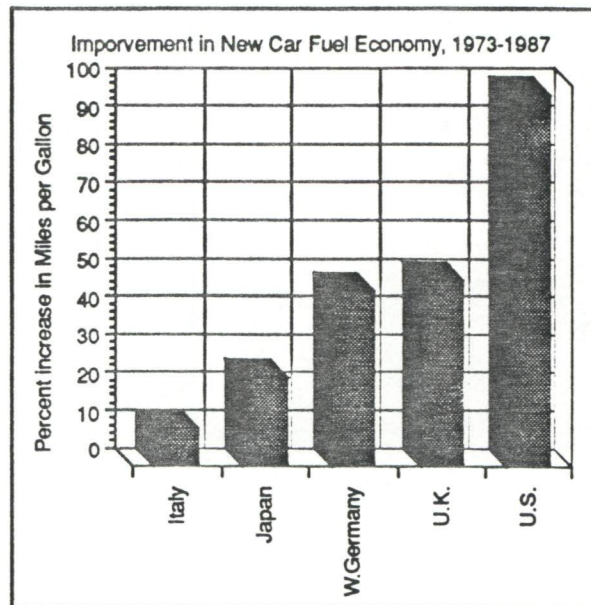
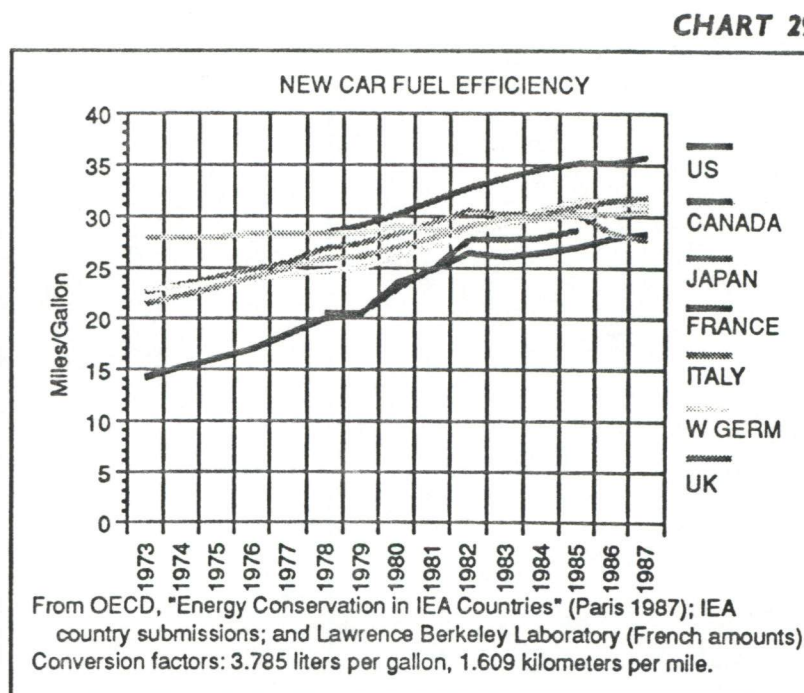


CHART 28



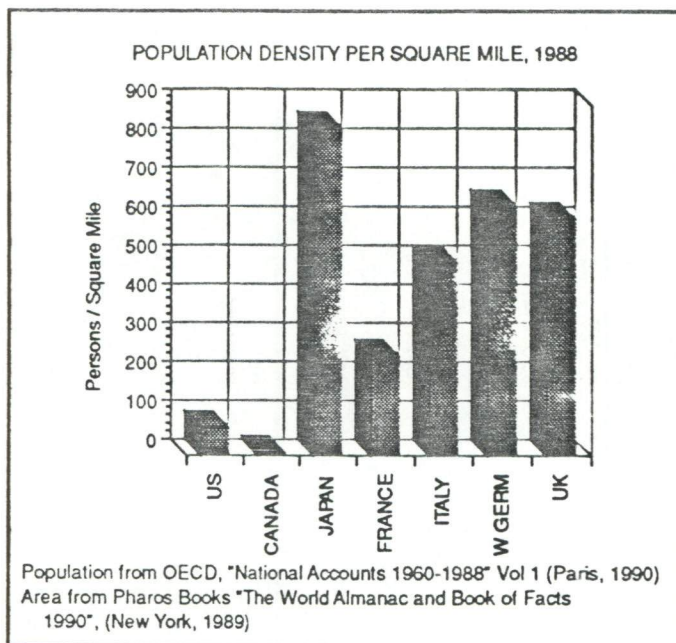


CHART 30

TRENDS: Pollution Expenditures

United States' declines in emissions of volatile organic compounds, carbon monoxide, CFCs, and, to some degree, the stabilization of carbon dioxide emissions over the period from the early 1970s to the present can be attributed to U. S. investment to protect and to clean up the environment. U. S. spending for all pollution control purposes over the period is shown in Chart 17. It has grown by 100 percent from 1972 to 1989.

U. S. pollution control spending has historically been larger compared to the country's Gross Domestic Product than spending by other countries for which data is available. Chart 18 shows pollution control spending as a percentage of Gross Domestic Product.

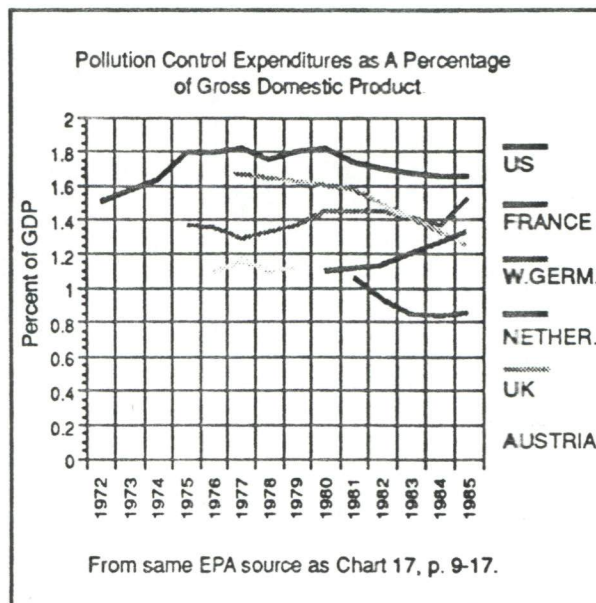


CHART 32

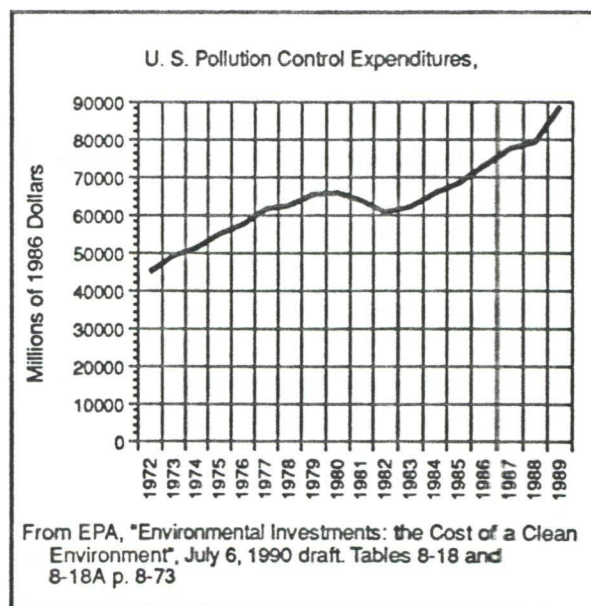


CHART 33

GLOBAL CHANGE RESEARCH

The Intergovernmental Panel on Climate Change (IPCC) stated that, "To reduce the current scientific uncertainties in each of these areas (as listed below) will require internationally coordinated research, the goal of which is to improve our capability to observe, model, and understand the global climate system. Such a program of research will reduce scientific uncertainties and assist in the formulation of sound national and international response strategies".

The U.S. Global Change Research Program (US/GCRP) has been developed as a central component of the United State's approach to global change, and more specifically to address these IPCC identified uncertainties.

In FY 1992, the U.S. plans to invest almost \$1.2 billion in this Program, which virtually doubles the U.S. commitment to the research program of the US/GCRP since it was initiated in FY 1990 (see chart below).

U.S. scientists have lead the development of an international global change research program. Other countries have joined the U.S. in a coordinated research effort to address critical scientific uncertainties, through such international programs as the World Climate Research Programme ((WCRP) and the International Geosphere-Biosphere Programme (IGBP). The total international research program, for which the U.S. provides about 50% of the financial support, is coordinated through United Nations scientific bodies (i.e., WMO,

IOC, and UNEP), through the International Council of Scientific Unions (ICSU), and through the recently established International Group of Funding Agencies for Global Change Research (IGFA).

The central task of the US/GCRP is to develop predictive understanding of the Earth's system's processes, particularly the climate aspects. It is the intent of the US/GCRP to provide leaders of government with the best possible scientific information as inputs to environmental policy decisions.

The highest priorities for the US/GCRP in FY 1992 are to:

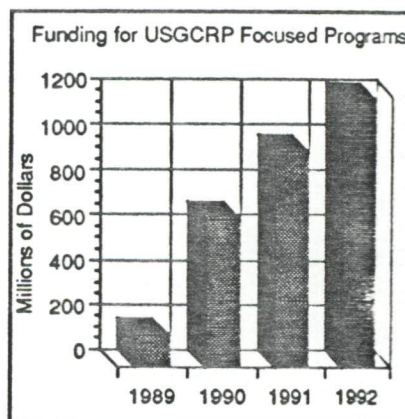
1. Enhance scientific research efforts that seek to *reduce the scientific uncertainties* identified during the IPCC scientific and impact assessments. Specifically, the USGCRP research will focus on understanding the processes affecting:

- *changing concentrations of greenhouse gases*, which are implicated in future global warming predictions;
- *clouds and radiative balance*, which strongly influence the magnitude of climate change at global and regional scales;
- *oceans*, which influence the timing and patterns of climate change;
- *land-surface hydrology*, which affects regional climate change and water availability;
- *polar ice sheets*, which affect predictions of global sea level changes; and
- *ecological dynamics*, which are impacted by and respond to climate change.

2. Enhance scientific *research to support the development and implementation of a comprehensive approach to greenhouse gas emissions reductions*, specifically a focus on:

- *sources and sinks of greenhouse gases*;
- *development of a quantitative index of radiative forcing*; and
- *use of economic models to generate future scenarios that cover multiple greenhouse gases and multiple sectors.*

The ultimate goals of the US/GCRP are to (1) Obtain a predictive understanding of the interactive physical, chemical, biological, geological, and social processes that regulate natural and human-induced changes in the total Earth system and, (2) Provide a strong scientific basis for national and international policy-making related to changes in the global environment and their regional impacts.



Master Graphic illustrating the
US/GCRP

CLIMATE CHANGE: Comprehensive Approach

Gases

H₂O

CO₂

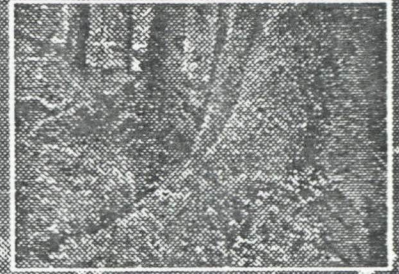
CH₄

COS

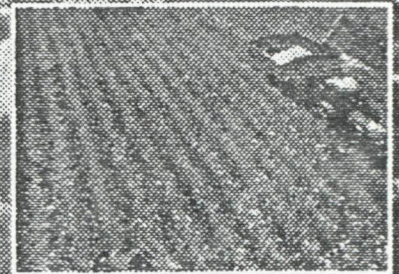
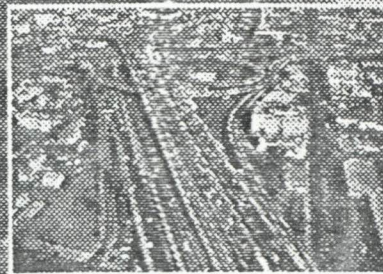
Sinks



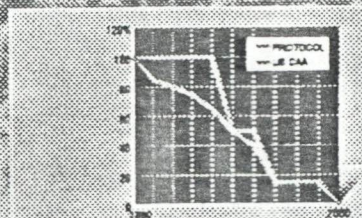
New Growth Forest

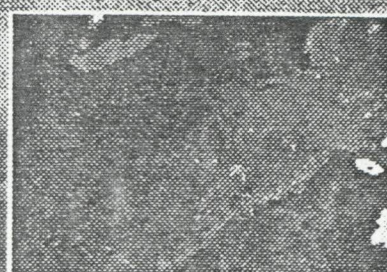
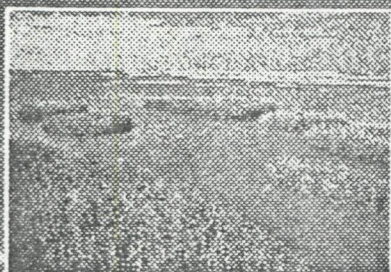
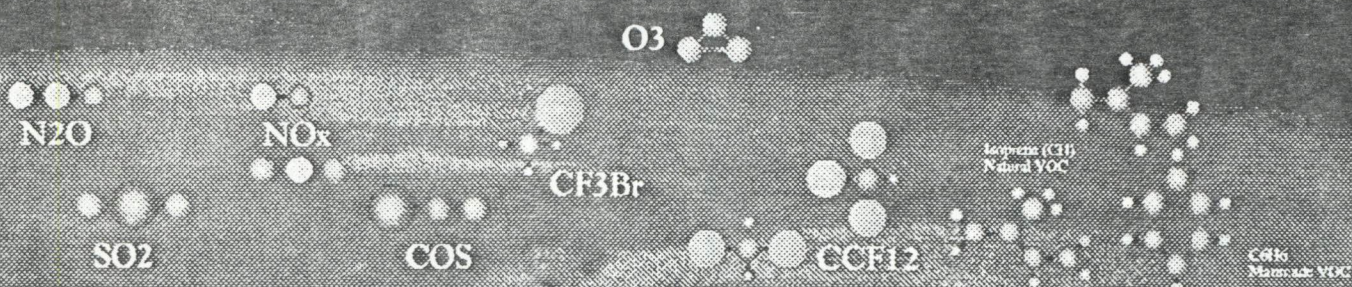


Sources



Global Warming Potential Index





Industrial/
Factories

GAS	Instantaneous Radiative Forcing per KG (ref. to CO_2)	Atmospheric Residence Years (estimated)	Relative Radiative Forcing Potential over Years		
			20	100	500
CO_2	1	120	1	1	1
CH_4	58	10	63	21	9
N_2O	206	150	270	290	190
CFC-11	3970	60	4500	3500	1500
CFC-12	5750	130	7100	7300	4500

Source: IPCC Scientific Assessment, 1990, Tables 2.9, 2.8

