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Global Warming (2 of 2) - 1990 [2]

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THE WHITE HOUSE

WASHINGTON

November 30, 1990

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY Allan

SUBJECT: Global Change Strategy Task Force Meeting

The Global Change Strategy Task Force met on Wednesday, November 28. The State Department discussed logistics for the Framework Convention negotiations, Justice gave a briefing on the Comprehensive Approach, and EPA gave a summary of recent work using the comprehensive approach to estimate U.S. greenhouse gas emissions.

Preparations for the Framework Convention on Climate Change.

The first negotiating session of the Framework Convention will be held in the Westfields Conference Center in Chantilly, Virginia, located 8 miles south of Dulles Airport. The location and surroundings of the conference center are conducive to a focus on work, rather than engaging in press contacts. The session will run from February 4 - 14, and a tentative agenda is attached (Tab A). One agenda item is election of a chair. At this time, there is only one viable candidate, Mr. Jean Ripert of France. He is considered by the U.S. to be qualified and reasonable.

The Comprehensive Approach.

The basics of the Comprehensive Approach were described to the group including its advantages, applications, potential objections to it, research needed to support the approach, options for including it into the Framework Convention, and options for developing the basis in the Convention for international trading. A summary of the briefing is attached. (Tab B)

U.S. Greenhouse Gas Emissions.

An EPA study was presented which uses the comprehensive approach and assumptions about U.S. environmental initiatives (such as the Clean Air Act) to estimate current and future U.S. emissions of greenhouse gases (Tab C). In addition, the sources of and underlying assumptions for these estimates is attached (Tab D). The full paper upon which this presentation was based is provided for your reference (Tab E).

Outstanding Issues.

There are seven broad categories of issues and tasks currently being worked on: 1) preparation of a climate action plan, 2) an economic feasibility study, 3) draft language on a comprehensive approach, 4) monitoring and science, 5) lesser developed country issues, 6) negotiating subgroups in relation to the IPCC, and 7) verification monitoring.

cc: Ede Holiday

THE WHITE HOUSE

WASHINGTON

GLOBAL CHANGE STRATEGY TASK FORCE

AGENDA

November 28, 1990

1. First Negotiating Session of the Framework Convention on Climate Change

    - o Preparations on Logistics Arrangements
    - o Preparations by PCC Working Group on Climate Change Subgroups

2. The Comprehensive Approach

3. Outstanding Issues for the Framework Convention

4. Other Business

Proposed Agenda

First Negotiating Session

Framework Convention on Climate Change

Washington, D.C.

February 4 - 14, 1991

1. Welcoming Remarks

2. Opening of Meeting: Remarks by WMO Sec-Gen Obasi, UNEP Ex Director Tolba, IPCC Chair Bolin

3. Adoption of Rules of Procedure: Draft to be available

4. Adoption of Agenda

5. Election of Chair

6. Election of Bureau: Refer to Prepcom report and recommendations

7. Organization of Work: To cover hours of sessions, meeting rooms, translation facilities (available only for negotiationg group and subgroups, not regional and other interest groups)

8. Credentials Committee

9. Statements by Governments: To be brief (10 min max) and focused on issues raised in IPCC and other supporting documents

10. Preparation of Legal Negotiating Text
    a. work program
    b. establishment of subgroups
    c. legal drafting group
    d. review of draft legal text

11. Future Work
    a. relationship with IPCC
    b. time and place of next meeting

12. Adoption of Report

13. Close of Meeting

Suggested timing for proposed agenda:

4	Monday	Agenda items 1 to 8
5	Tuesday	Agenda item 9
6	Wednesday	Agenda item 9 cont'd
7	Thursday	Agenda item 10
8	Friday	Agenda item 10 cont'd
11	Monday	Agenda item 10 cont'd
12	Tuesday	Agenda item 10 cont'd
13	Wednesday	Agenda item 10c and 11
14	Thursday	Agenda item 10d, 12 and 13

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01. Paper	"A Comprehensive Approach to Climate Change", Briefing to the DPC Global Change Strategy Group, Presentation by the Department of Justice, Environment & Natural Resources Division (13 pp.)	11/28/90	~~P-5~~	

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AR Disposition Date:		**MR Disposition Date:**	

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(b)(9) Release would disclose geological or geophysical information

A COMPREHENSIVE APPROACH TO CLIMATE CHANGE

Briefing to the DPC Global Change Strategy Group

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

November 28, 1990

- OFFICIAL USE ONLY -

"Comprehensive Approach" described

- An approach or heuristic to guide consideration of climate change issues.

- Considers all anthropogenic inputs: net emissions (sources less sinks) of relevant trace gases, weighted by the environmental impacts of each gas.

- Considers the several trace gases of interest:

  Carbon dioxide (CO_2)
  Methane (CH_4)
  Nitrous oxide (N_2O)
  Chlorofluorocarbons (CFCs)
  Hydrochlorofluorocarbons (HCFCs)
  Tropospheric Ozone (O_3) and its precursors:
    Nitrogen oxides (NO_x)
    Carbon monoxide (CO)
    Volatile organic compounds (VOCs)

- Considers sources and sinks of these trace gases in every sector of human activity:

  Energy generation
  Transportation
  Agriculture
  Forestry and land clearing
  Industry

- Employs a measure, such as an index, of the comparative environmental impacts of the gases

Anthropogenic Sources & Sinks of Selected Gases

Gas	Sources	Sinks
Carbon dioxide (CO_2)	Fossil fuel combustion Land clearing	Forests Grasses Soils Ocean biota & storage
Methane (CH_4)	Enteric fermentation in livestock Rice cultivation Wetlands Landfills Natural gas drilling, venting, transmission Coal mining Biomass combustion	Atmospheric OH interaction Soil removal
Nitrous oxide (N_2O)	Agricultural fertilizers Land clearing	Soil removal
Halocarbons (CFCs and related)	Refrigerants Aerosol propellants Foam blowing agents Solvents and cleaning agents Fire retardants	
Tropospheric Ozone (O_3)	Precursors: CH_4, CO, VOCs, in the presence of NOx 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 (NOx)	Fossil fuel combustion Biomass combustion Agriculture	
Volatile Organic Compounds (VOCs)	Fossil fuel combustion Biomass combustion Industry	Atmospheric OH interaction
Aerosols/sulfates (e.g. SO_2)	Fossil fuel combustion	

Comparing trace gases

- Need for a measure of relative impacts. A measure, or index, is needed to compare the environmental impacts of each trace gas. This measure ensures accounting for activities' overall impacts on the environment, while allowing decision makers the flexibility to fashion a mix of efforts directed at diverse gases.

- Weighting can't be avoided. Any policy will employ some index to weight the gases, whether implicit or explicit. A CO_2-only policy implicitly weights the other gases at zero.

- GWP. One such measure is the "Global Warming Potential" (GWP) index, presented in the IPCC Report. The GWP measures the relative radiative forcing of each gas over time -- its potential to warm the atmosphere.

Gas	Instantaneous radiative forcing per kg	Atmospheric residence years (estimated)	Relative radiative forcing potential over years		
			20	100	500
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, tables 2.3 and 2.8.)

- Some uncertainties remain in the GWP values, relating principally to the residence times of gases such as CO_2 and N_2O. They do not warrant abandoning the index.

- Time and discounting need further discussion.

- Other comparative measures might also be developed. For example, a "global change index" could incorporate other salient global impacts of the gases in addition to their radiative forcing. These other global impacts include beneficial plant enrichment from CO_2, and adverse stratospheric ozone depletion from CFCs and some of their substitutes. Ignoring these impacts could lead to perverse results, such as a limit on warming that induces other adverse environmental consequences. Yet a multiple attribute index would require a challenging analytic exercise, and its development should initially proceed as a complement not a rival to a radiative forcing index.

Comprehensive approach has multiple applications

- Research. Designing research strategies to generate the most valuable information, by focusing attention on the climate variables of concern for which information is lacking.

- Technology evaluation. Calculating the effects on net emissions of new technologies and practices. Possible uses in foreign technology assistance, federal R&D funding, assessments of technology choices encouraged by other regulatory programs.

- Inventories. Calculating current net emissions of relevant trace gases, by nation and sector.

- Report cards. Calculating the likely effects on net emissions of current policy actions.

- Policy choices. Calculating the effects on net emissions of potential policy actions proposed by others or considered by the U.S.

- Policy design. Defining any agreed response measures in terms of a comprehensive approach, accounting for and allowing flexibility among all relevant gases, sources and sinks.

"How to" and "how much"

- In general, the comprehensive approach addresses "how to," that is, the design of cost-effective responses (including research, technology development, limitations, etc.). It does not directly address the question of "how much" response to potential climate change is desirable; that is the province of overall cost-benefit analysis, which considers the aggregate costs and benefits of change and of actions to respond.

- The comprehensive approach does shed light on some approaches to the question of "how much," by ensuring attention to the arguably limited environmental benefits and high economic costs of piecemeal policy measures.

Advantages of a Comprehensive Approach to Policy Design

A. The dominant tenor of climate policy discourse has been piecemeal, addressing each trace gas and each sector separately. Most policy proposals, and most data collection efforts, have focused on energy sector CO_2 emissions.

B. Comprehensive approach offers environmental advantages

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

- o Administration efforts to employ better approaches:

  -- multimedia approach to solid and hazardous emissions
  -- multipollutant approach to air emissions
  -- multimedia enforcement actions
  -- comprehensive approach to climate context

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

Examples:

(1) Piecemeal policy aimed at CO_2 alone could induce fuel-switching from coal or oil to natural gas, with attendant reduced CO_2 emissions from combustion, but increased CH_4 output from transmission leakage.

Methane offset from fuel-switching to Natural Gas:

	Typical grams of CO2 emitted per MJ (in Sweden)	CH4 leakage rate that offsets 100% of CO2 savings
Coal	92	6%
Oil	78	4%
Nat. Gas	56	--

(Calculated from Rodhe, Science 8 June 1990, using Rodhe's GWP figure of CH_4 = 10 GWP per mole CO_2 over 100 year integration period.)

Current average Natural Gas transmission CH4 leakage rates:

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

(2) Piecemeal focus on limiting agricultural CH_4 could induce use of nitrogenous fertilizers that reduce CH_4 emissions per yield but raise N_2O emissions.

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

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

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

C. Comprehensive approach offers economic and social advantages

- o Piecemeal approach is economically inefficient. Piecemeal policy would preclude alternatives that achieve the same environmental outcome at less cost. For example, a policy aimed only at energy sector CO2 would bar less costly abatement options such as afforestation, CH4 reductions, attention to CFC-substitutes, or N2O reductions.

- o Flexibility reduces costs. The costs of different options will vary across nations, so to minimize costs each ought to have the flexibility to build its least-cost policy mix among the gases and sectors.

  (Even if a multi-gas inventory would rank some nations higher in net emissions than they would under a single-gas accounting, all nations could gain as the marginal cost of abatement is reduced through greater flexibility.)

- o Burden sharing. A comprehensive approach provides a more "level playing field" across nations, in contrast to a piecemeal approach which effectively singles out nations with one pattern of economic and social activity. Offers the possibility of smoother, and more sober, international cooperation.

Potential objections to a comprehensive approach

- Data and monitoring of sources and sinks are inadequate

  -- Build better data and monitoring

  -- Employ carefully chosen proxies or surrogates for difficult-to-measure emissions

  -- Design incentives for monitoring improvements, such as offering emissions credit to those who demonstrate better monitoring techniques.

- GWP Index is uncertain

  -- Boulder workshop suggests fundamentals well accepted

  -- Work toward improvements

  -- Absolute precision may not be required initially; changes in index numbers could be made at wide intervals and/or prospectively

- Other discrete actions will have already been taken, e.g. forestry agreement, CFCs, VOCs

  -- Integration of prior and current actions into comprehensive approach will be necessary

- CFCs should not be included in comprehensive basket

  -- Comprehensive approach would not allow violation of the Montreal Protocol

  -- CFCs are a major share of radiative forcing, and their elimination should be recognized

  -- Some nations are doing more to reduce global CFCs than others, and their contribution should be recognized

  -- Faster reductions, or reductions in other substances not controlled, or in other nations, could earn credit; this would provide helpful incentives in support of the Montreal Protocol

  -- CFC substitutes may be quite important to radiative forcing

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

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

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

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

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

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

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

Options for Including a Comprehensive Approach in the Convention

(1) Monitoring. Comprehensive source and sink monitoring: cooperative international networks addressing all relevant trace gases. Create institutions for data sharing, harmonizing methodologies, R&D on new techniques.

(2) International inventories. Build the capacity to estimate international net emissions of relevant trace gases: baseline levels and changes due to policy actions. National reporting, workshops to compare numbers and methods.

(3) Index. Cooperative development and refinement of an index. Create institutional expert body to conduct regular reassessments and keep policy makers informed of research developments.

(4) Framing policy. Ensure that any limitations obligations (if any, whether now or in the future) are defined in terms of a comprehensive approach. This could be required, or at least endorsed, in the convention.

(5) Advance assurance. Give advance assurance that current actions will receive "credit" against any future limitations obligations, in accordance with a comprehensive approach.

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

Cons: Requires debate over baseline.

(6) Technology evaluation. Employ a comprehensive approach to assess any technology transfer activities.

Options for Laying the Basis for International Trading in the Convention

(a) REIOs. Broaden the notion of "regional economic integration organization" (REIO) to allow any group of nations to work together. The term REIO is employed in the Montreal Protocol to allow regional groups like the EC to form a group-wide CFC emissions bubble. It could be broadened to allow joint undertakings by less formalized groups of states, and by non-contiguous states.

(b) Joint cooperation. Include language acknowledging that any obligations can be met through "joint cooperative arrangements." Applies to technology development, emissions limitations, other obligations.

(c) Registry. Develop an international information center on trades. The center could initially gather information and provide advice on how to arrange and implement effective trades. It could start with information on, e.g., debt-for-nature swaps and EC bubble activities. It could grow to become a trading registry if full-scale international trading developed.

(d) Financial and technology transfers. Incorporate emissions credits into international technology transfer and financial assistance arrangements. Funds and technology transferred by donor countries, directly or through a global environmental funding facility, could earn credits for the donors corresponding to the net emissions change (calculated in terms of a comprehensive approach) achieved by the transfer. The donor could then submit the credit in compliance with any international limits on emissions that might later be agreed.

GREENHOUSE GAS EMISSIONS

TRENDS AND POLICY OPTIONS

GREENHOUSE GAS INVENTORY

- **GREENHOUSE GASES:**

  CARBON DIOXIDE (CO_2)

  METHANE (CH_4)

  CHLOROFLUOROCARBONS (CFCs)

  NITROUS OXIDES (N_2O)

  TROPOSPHERIC OZONE (O_3)

- **GASES THAT AFFECT CONCENTRATIONS OF GREENHOUSE GASES:**

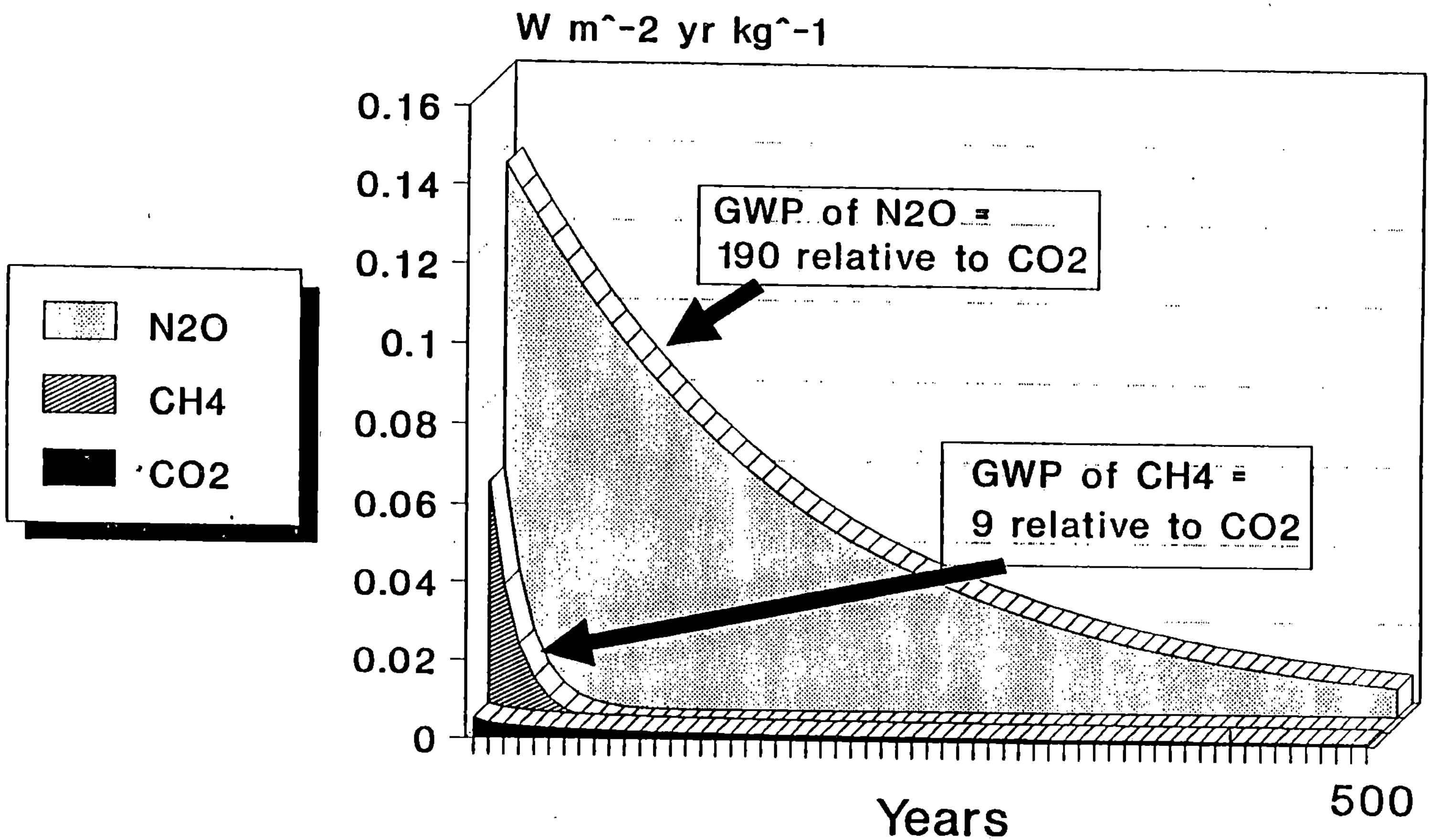
  VOLATILE ORGANIC COMPOUNDS (VOCs)

  CARBON MONOXIDE (CO)

  NITROGEN OXIDES (NO_x)

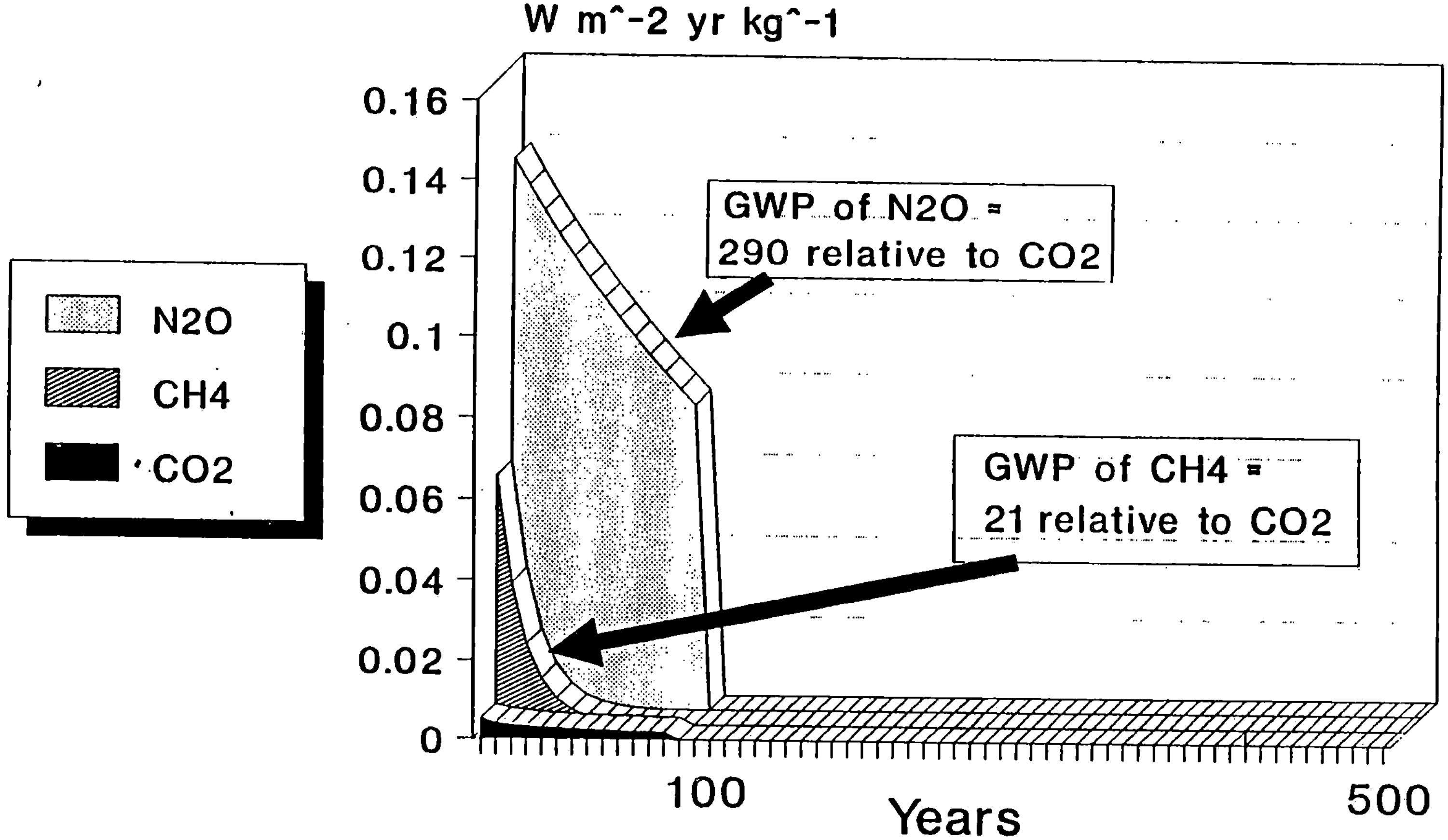
- **PROBLEM: NEED WAY TO TRANSLATE VARIOUS GASES INTO A COMMON CURRENCY**

GHG Time Profiles
500 Years



Radiative forcing of a gas is expressed as a change in the flux of energy, i.e., watts per sq. meter per kg of gas.

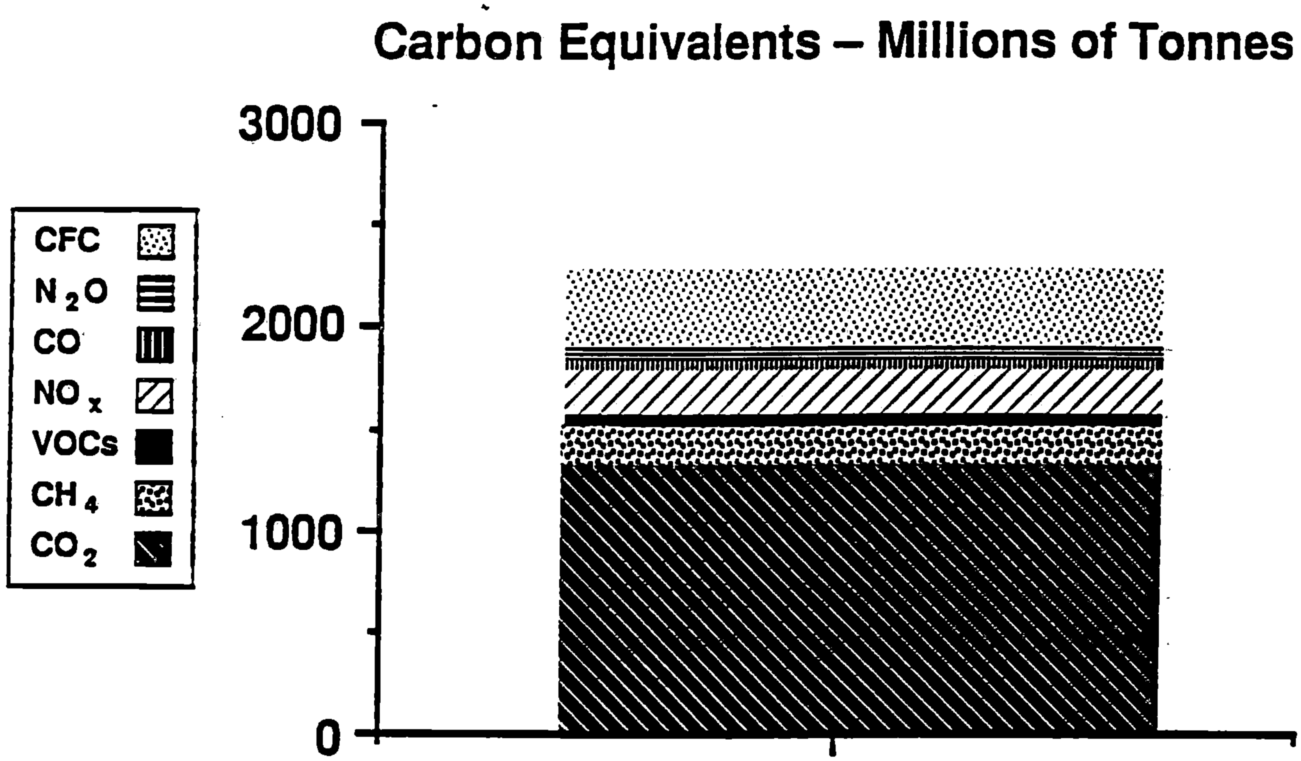
GHG Time Profiles
100 Year



Radiative forcing of a gas is expressed as a change in the flux of energy, i.e., watts per sq. meter per kg of gas.

Trace Gas	Estimated Lifetime, years	Global Warming Potential — Integration Time Horizon, Years		
		20	100	500
Carbon Dioxide	*	1	1	1
Methane - inc indirect	10	63	21	9
Nitrous Oxide	150	270	290	190
CFC-11	60	4500	3500	1500
CFC-12	130	7100	7300	4500
HCFC-22	15	4100	1500	510
CFC-113	90	4500	4200	2100
CFC-114	200	6000	6900	5500
CFC-115	400	5500	6900	7400
HCFC-123	1.6	310	85	29
HCFC-124	6.6	1500	430	150
HFC-125	28	4700	2500	860
HFC-134a	16	3200	1200	420
HCFC-141b	8	1500	440	150
HCFC-142b	19	3700	1600	540
HFC-143a	41	4500	2900	1000
HFC-152a	1.7	510	140	47
CCl_4	50	1900	1300	460
CH_3CCl_3	6	350	100	34
CF_3Br	110	5800	5800	3200
INDIRECT EFFECTS				
Source Gas	Greenhouse Gas Impacted			
CH_4	Tropospheric O_3	24	8	3
CH_4	CO_2	3	3	3
CH_4	Stratospheric H_2O	10	4	1
CO	Tropospheric O_3	5	1	0
CO	CO_2	2	2	2
NO_x	Tropospheric O_3	150	40	14
NMHC	Tropospheric O_3	28	8	3
NMHC	CO_2	3	3	3

Current Emissions
1987
(100 Year GWP Factors)



	1987
CO_2	1310
CH_4	235
VOCs	72
NO_x	218
CO	52
N_2O	74
CFC	367
Total	2328

EMISSIONS REDUCTIONS EXPECTED IN THE YEAR 2000 DUE TO CURRENT ENVIRONMENTAL COMMITMENTS AND OTHER INITIATIVES ASSUMED IN THE ANALYSIS

CURRENT COMMITMENTS	MILLIONS OF TONNES REDUCED (Carbon Equivalents) 2000[4]
o TREE INITIATIVE	~9
o DOE ENERGY EFFICIENCY INITIATIVES	28
o DOE APPLIANCE STANDARDS	4
o DOE RENEWABLE INITIATIVES	4
o CLEAN AIR ACT	17
o LANDFILL REGULATION	44
o CFC PHASEOUT & MONTREAL PROTOCOL	551

[4] Assumes a 100 year time horizon in GWP calculations.

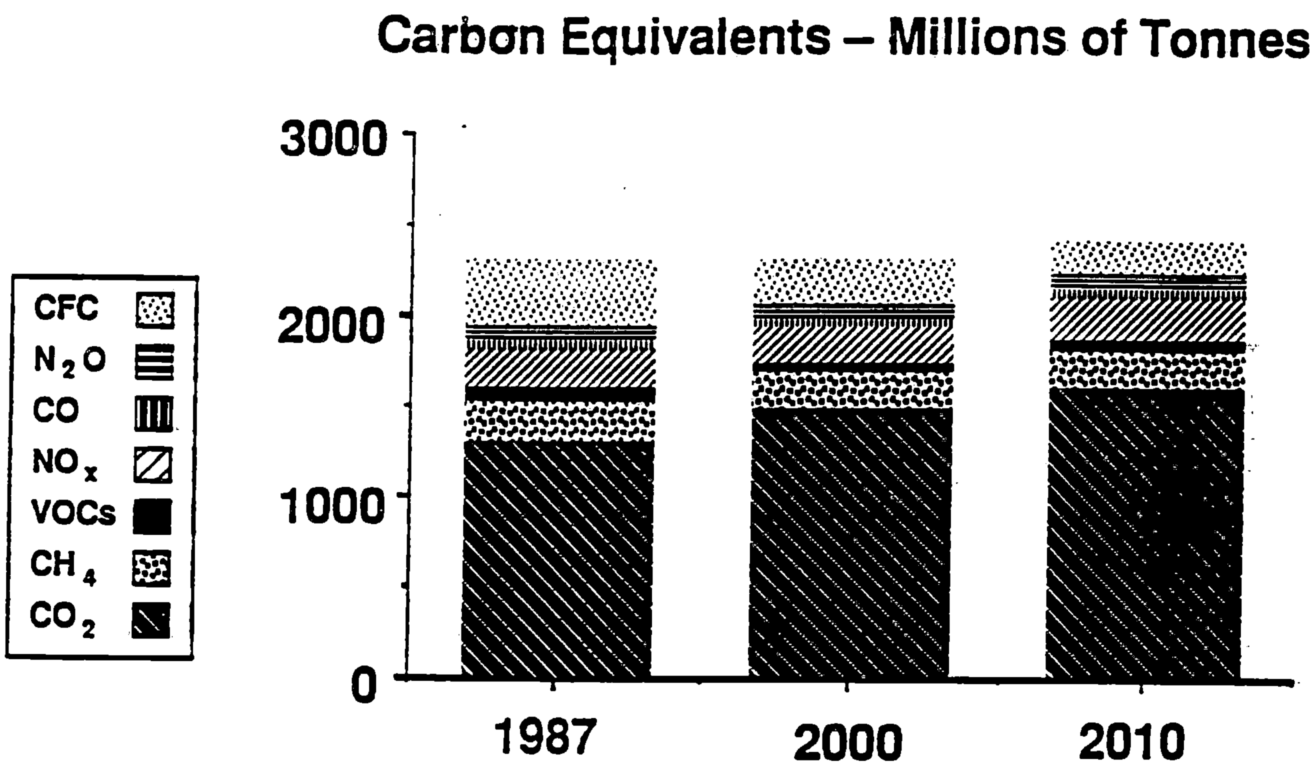
DOE-RELATED CO_2 EMISSIONS REDUCTIONS USED IN EPA'S GHG EMISSIONS INVENTORY

ACTION/PROGRAM	2000	
	CO_2	Carbon
DOE Appliance Standards (Refrigerators, Washers, Dryers, Dishwashers)	16.0	4.4
DOE Efficiency Initiatives	**102.0**	**27.8**
Federal Buildings Lighting	5.0	1.4
Commercial Buildings Lighting	9.0	2.5
Promote State LCUP	33.0	9.0
State Adoption of Interim Building Standards	30.0	8.2
Energy Analysis and Diagnostic Centers	22.0	6.0
HUD Adoption of DOE Building Standards	3.0	0.8
DOE Renewable Initiatives	**15.0**	**4.1**
Expanded Hydro Power	13.0	3.5
Photovoltaic Technology Transfer	2.0	0.5
Clean Air Act	**63.0**	**17.2***
Acid Rain	60.0	16.4
Transportation Biofuels and Natural Gas Use	3.0	0.8
GRAND TOTAL	196.0	53.5

* Does not include reductions of 51 million metric tonnes due to decreases in NO_x (19.6 million tonnes), CO (7.4), and VOCs (23.7).

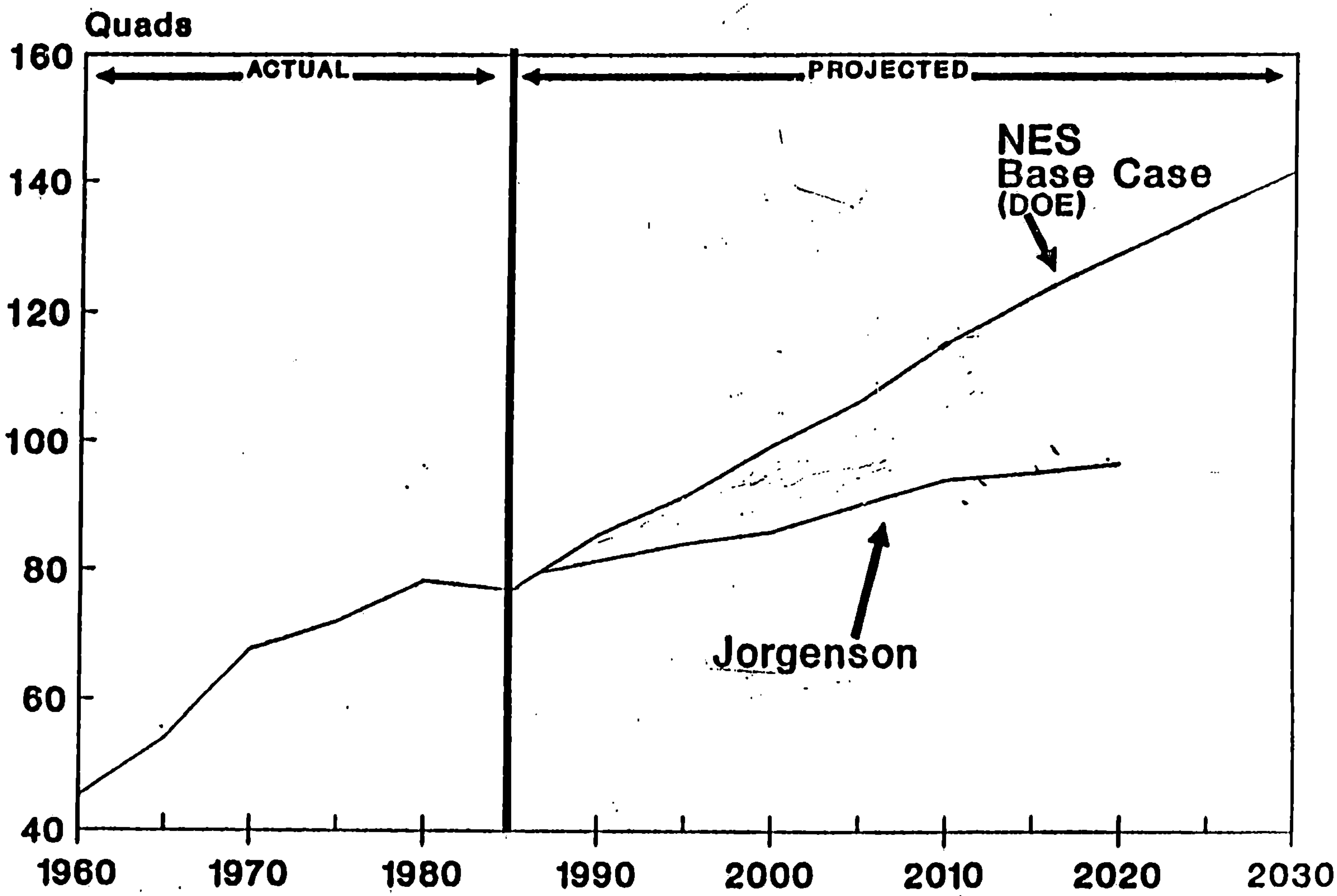
Emissions

(With Current Commitments)
(100 Year GWP Factors)

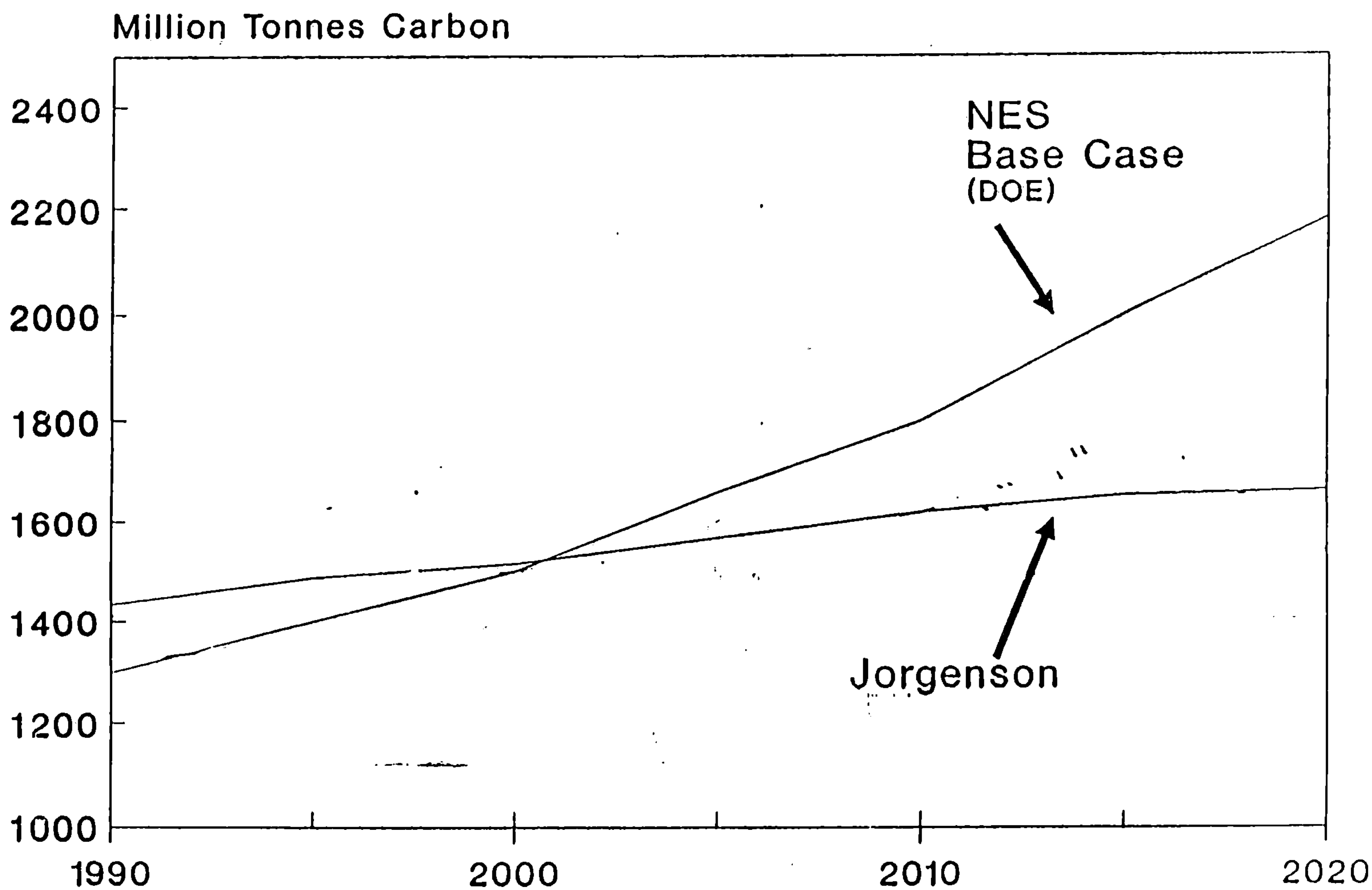


	1987	2000	2010
CO_2	1310	1503	1627
CH_4	235	208	212
VOCs	72	48	50
NO_x	218	199	235
CO	52	45	46
N_2O	74	74	74
CFC	367	256	188
Total	2328	2332	2430

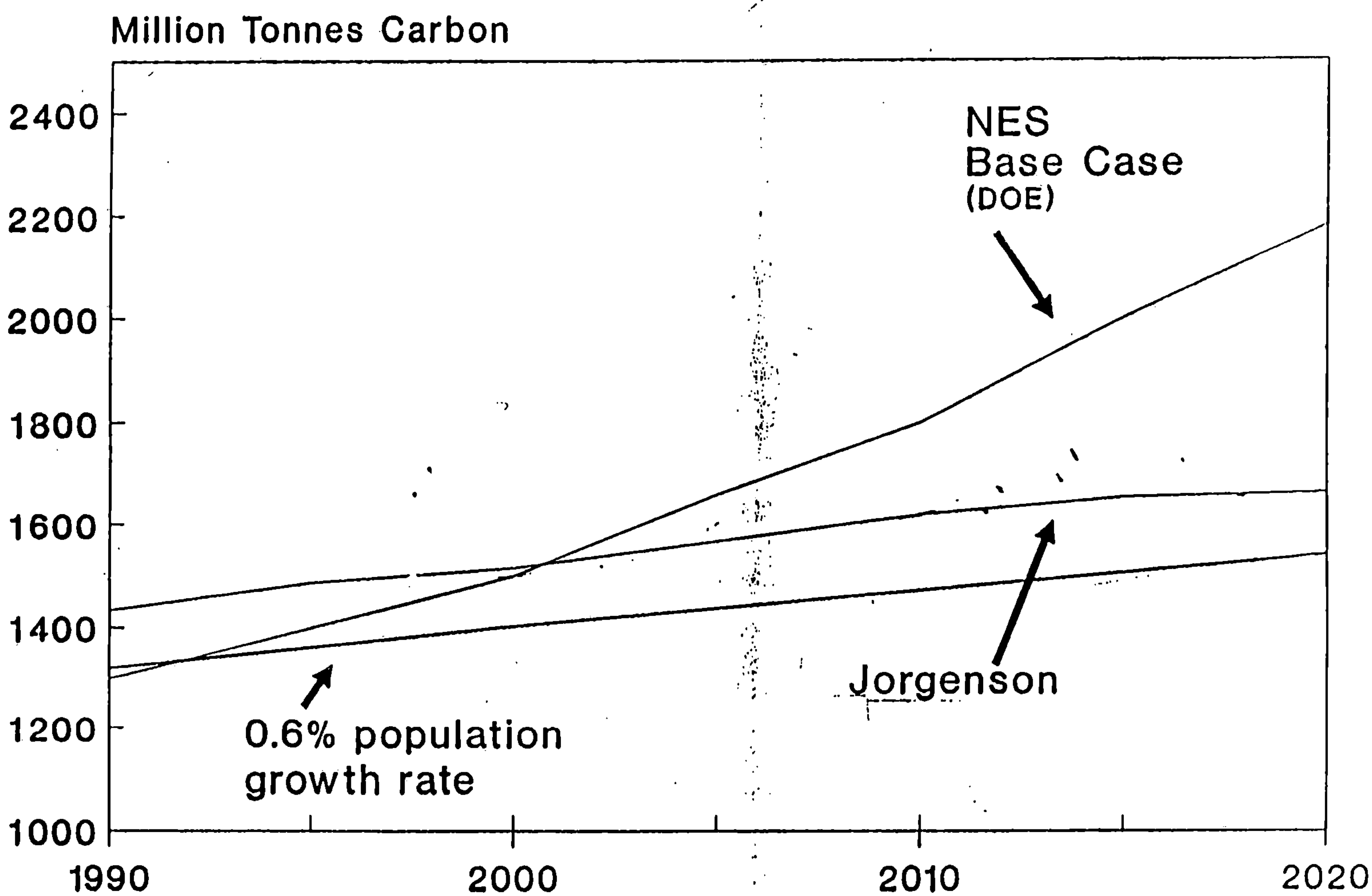
U.S. Primary Energy Consumption



U.S. CO2 Emissions



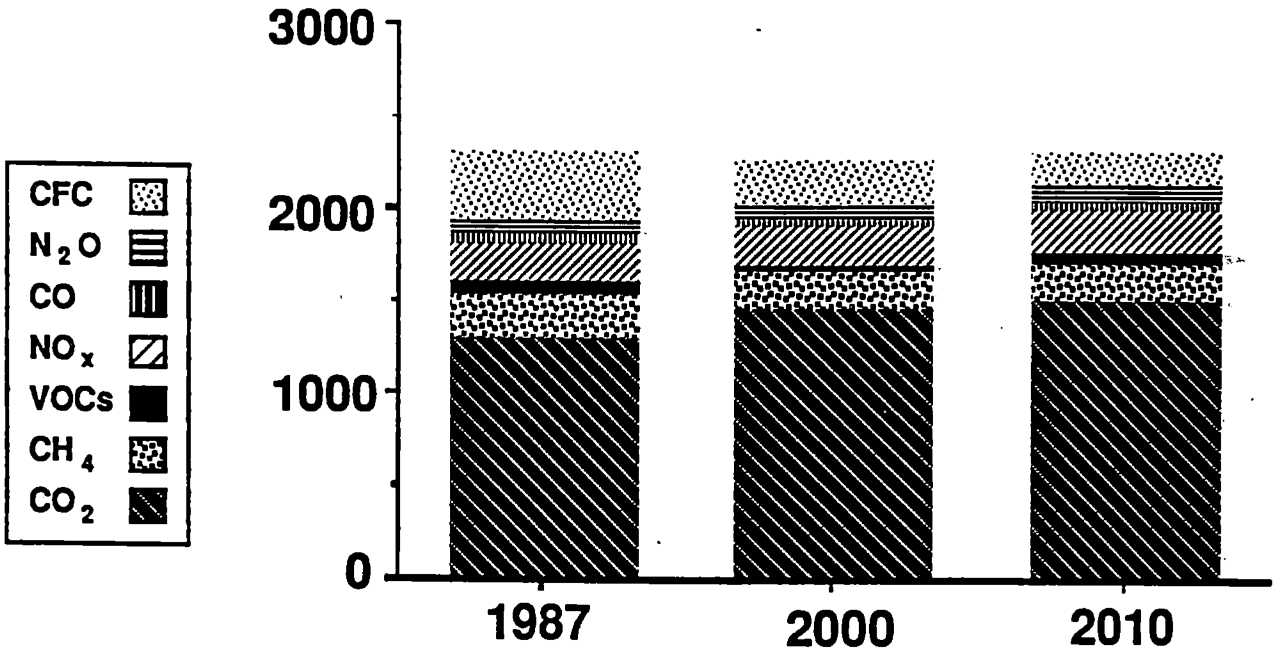
U.S. CO2 Emissions



Emissions

(With Current Commitments)
(100 Year GWP Factors)

Carbon Equivalents – Millions of Tonnes



	1987	2000	2010
CO_2	1310	1453*	1498*
CH_4	235	208	212
VOCs	72	48	50
NO_x	218	199	235
CO	52	45	46
N_2O	74	74	74
CFC	367	256	188
Total	2328	2283	2303

* CO_2 estimates derived from baseline emissions projections in Jorgenson and Wilcoxen (1990)

SOURCES OF GREENHOUSE GAS EMISSIONS ESTIMATES

The following appendix documents the sources of the emissions estimates for each of the greenhouse gases, as well as important underlying assumptions. Documentation is presented for: (i) the 1987 "base case," (ii) emissions in 2000 without current environmental commitments, and (iii) emissions in 2000 with current environmental commitments.

CO_2:

Estimates of CO_2 emissions for 1987 and 2000 (without current environmental commitments) were derived from figures provided by the U.S. Department of Energy (DOE) to the Energy and Industry Subgroup (EIS) of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change (IPCC).

CO_2 emissions reductions in the year 2000 were estimated by DOE for the following current environmental commitments:

- **DOE Energy Efficiency Initiatives**
- **DOE Appliance Standards**
- **DOE Renewable Initiatives**
- **Proposed Clean Air Act Legislation and DOE Transportation Fuels Program**

A detailed discussion of each of these initiatives follows:

I. **DOE Energy Efficiency Initiatives (102 million tons CO_2)**

- **More Efficient Lighting in Federal Buildings (5 million tons CO_2)**

  It is assumed that federal agencies fully comply with the relevant Executive Order by 2000. Electricity savings would be 0.05 quad.

- **More Efficient Lighting in Commercial Buildings (9 million tons CO_2)**

  It is assumed that approximately one-half of buildings convert to high efficiency lighting with an average savings of 25 percent of electrical demand for lighting. Electricity savings are 0.125 quad.

- **Promotion of State Efforts to Institute Utility Integrated Resource Planning for End-use Energy Efficiency (33 million tons CO_2)**

  This and CO_2 reductions from the Clean Air Amendments are linked. Many states are emphasizing Integrated Resource Planning, although methods of analysis and implementation plans are not fully developed for all states. Due to the impetus for Clean Air Act legislation, the need for coal/fossil fuel generation may be reduced by 10-15 percent due to demand reduction. Supporting DOE programs would primarily include methods development and promotional options. Hence, reductions by the year 2000 would probably be lower than would otherwise be achieved. A 7.5 percent reduction in added demand is assumed, resulting in an electricity savings of 0.48 quad.

- **Adoption of DOE Interim Building Standards by the States (30 million tons CO_2)**

  The DOE program includes dissemination of information and provision of voluntary guidelines. States could transform the guidelines into enforceable standards. Federal buildings must meet new standards beginning in 1989. It is assumed that there would be a 50 percent acceptance rate for new non-Federal buildings and a 20 percent demand reduction per building. Savings would be .43 quads of electricity.

- **Expansion of the Energy Analysis and Diagnostic Centers to Increase Energy Audits (22 million tons CO_2)**

  Program expansion would occur to 40 energy efficiency engineering centers by 2000, resulting in audits of 3 percent of eligible industrial facilities by 2000. The estimate assumes implementation of 60 percent of audit recommendations, with a 15 percent improvement in energy efficiency. Total savings of all fuels would be .28 quads, including .05 quads of electricity.

- **Use of DOE Building Standards by HUD in Public Housing Assistance Programs (3 million tons CO_2)**

  Although the program is still being designed, it is assumed that it will be successful in providing a required 25 percent efficiency increase in buildings that are refurbished. It is projected that 1.4 million units in the 7 major public assistance programs will be retrofitted by 2000, resulting in annual efficiency gains of 0.05 quads.

II. <u>DOE Appliance Standards</u> (16 million tons CO_2)

The new appliance standards refer to refrigerators, freezers, clothes washers, clothes dryers, and dishwashers. DOE appliance standards call for an increase in the efficiency of refrigerators and freezers by 25 percent by 1993. The standards applying to refrigerators and freezers are already in the law. It is assumed that 1993 and subsequent model year refrigerators and freezers meet the regulation exactly. The remaining standards are still being promulgated. All of the standards are due to take effect in 1993.

It is assumed that patterns of consumer purchases will be similar to today's buying and replacement patterns. Annual electricity savings due to units installed by the year 2000 would be 0.15 quad.

III. <u>DOE Renewable Initiatives</u> (15 million tons CO_2)

- **<u>Expanding Hydropower Capacity</u> (13 million tons CO_2)**

  The DOE program involves working with permitting/development authorities to streamline present complex processes. At maximum levels, 20,000 Mw of capacity could be added by the year 2000. It is assumed that 25 percent of this could be realized by the year 2000, reducing fossil energy electricity requirements by .27 quads. (EPA further reduced this estimate by 50 percent.) Present capacity is 90,000 Mw.

- **Transfer of Photovoltaic Technology: (2 million tons CO_2)**

  This estimate assumes that the U.S. initiative would be 675 Mw of installed capacity by 2000, or a savings of .03 quads of demand for fossil fuel electricity.

IV. Proposed Clean Air Act Legislation and DOE Transportation Fuels Program (63 million tons CO_2)[10]

- **Conservation Due to Clean Air Act Provisions on Acid Rain Controls: (60 million tons CO_2)**

  Clean Air Act amendments place requirements for SO_2 reduction on present coal facilities but allow the facilities to determine how these reductions will be met. New facilities must obtain offsetting emissions allowances. One method to reduce emissions allowance purchase requirements would be to reduce end-use demand supplied by older coal-fired plants (for largest SO_2 reductions). EPA has estimated that this reduction could be as great as 10 percent of present coal-fired generation. Because of the linkage with state efforts to institute Utility Integrated Resource Planning for end-use energy efficiency, the estimate here is cut to 5 percent of present coal-fired generation, with an annual CO_2 reduction of 60 million tons.

- **Increased Use of Biofuels for Transportation (1 million tons CO_2)**

  Preliminary estimates assume 10 percent ethanol fuel for 13 percent of gasoline used in year 2000. It is also assumed that the ethanol is made from a biomass feedstock that is replaced or recycled. This represents 50 percent of the expected oxygenated fuel required by the Clean Air Act.

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[10] This does not include reductions of 51 million metric tonnes due to decreases in NO_x (19.6 million tonnes), CO (7.4), and VOCs (23.7).

- **Increased Use of Natural Gas in Central Fleets Due to Clean Air Act (2 million tons CO_2)**

  One percent of the Nation's use of gasoline would be replaced by compressed natural gas, providing a 20 percent decrease in CO_2 for that amount.

METHANE:

Estimates of methane (CH_4) emissions for 1987 were derived from figures provided by DOE to the EIS of the IPCC Response Strategies Working Group. Estimates of emissions for 2000 (without current environmental commitments) were derived from the IPCC EIS and the Agricultural Working Group. For both 1987 and 2000, the estimates were adjusted upward by 6 million tonnes by EPA to reflect its landfill estimates.

Estimates of methane emission reductions in the year 2000 were obtained from EPA's Office of Air Quality Planning and Standards (OAQPS). The estimates reflect methane reductions that arise due to a 250 Mg/yr landfill standard.

VOCs:

The estimate of 1987 VOC emissions were provided to OAQPS by E.H. Pechan & Associates and derived from the ERCAM-VOC model. The estimate uses the 1985 NAPAP emissions inventory as a base and (i) adjusts auto emissions using EPA's MOBILE4 model, and (ii) includes estimates of emissions from hazardous waste treatment storage.

VOC emissions for the year 2000 (without current environmental commitments) are assumed to remain at 1987 levels. This presumption was made in order to account for future implementation of the current Clean Air Act.

VOC emission reductions in the year 2000 were derived by EPA/OAQPS based on ERCAM-VOC model runs. The model runs assumed the provisions of the Senate version of the Clean Air Act.

NO_x:

1987 emission estimates for NO_x were obtained from EPA (1989). Emissions in the year 2000 (without current environmental commitments) were assumed to remain at 1987 levels. Estimates of NO_x emissions reductions in 2000 were provided by OAQPS, and assumed implementation of the Senate version of the Clean Air Act.

CO:

1987 emission estimates for carbon monoxide (CO) were obtained from EPA (1989). Emissions in the year 2000 (without current environmental commitments) were assumed to remain at 1987 levels. Estimates of CO emissions reductions in 2000 were provided by the EPA Office of Mobile Sources (OMS), and assumed implementation of the Senate version of the Clean Air Act.

N_2O:

Estimates of N_2O emissions for 1987 were derived from figures provided by DOE to the EIS of the IPCC Response Strategies Working Group. Emissions in the year 2000 (without current environmental commitments) were assumed to remain at 1987 levels. Emissions in the year 2000 with current environmental commitments were also assumed to remain constant at 1987 levels.

CFCs:

EPA emissions estimates for 1987, 2000 (without current commitments), and 2000 with current commitments were obtained from EPA's Office of Air and Radiation (OAR). OAR estimates assumed that new production of CFCs declines over time, the stock of CFCs rises, and the number of CFC substitutes increases.

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POLICY IMPLICATIONS OF A COMPREHENSIVE GREENHOUSE GAS BUDGET

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POLICY IMPLICATIONS OF A COMPREHENSIVE GREENHOUSE GAS BUDGET

ABSTRACT

A comprehensive approach that accounts for the differences in atmospheric lifetimes and radiative forcing effects of the greenhouse gases has been implemented, using values for the "Global Warming Potentials" of greenhouse gases recently published by the Intergovernmental Panel on Climate Change. Emissions of each greenhouse gas have been expressed in terms of a common metric, "carbon equivalents," permitting the integration of all gases into an overall greenhouse gas index.

Using the comprehensive approach, current U.S. emissions of greenhouse gases have been estimated, and projections made of U.S. emissions in the year 2000, given particular assumptions about future U.S. environmental initiatives and economic growth.

Given current U.S. environmental commitments, total greenhouse gas emissions (including CFCs) will be held to 1987 levels in the year 2000. If CFCs are not included in the total greenhouse gas budget, total emissions in the year 2000 will exceed 1987 levels by approximately 115 million metric tonnes of carbon equivalents.

The comprehensive approach provides policymakers with a valuable analytic tool. It provides a methodology with which they can evaluate an integrated set of policy options intended to achieve emissions reductions of all greenhouse gases. Also, by focusing on sources of all greenhouse gases, and not just on those that emit CO_2, it permits a consideration of a wider diversity of policy options. This, in turn, enables policymakers to achieve reductions in greenhouse gas emissions in a more efficient, least-cost manner. Regardless of the magnitude of the reductions under consideration, policymakers will be able to achieve incremental reductions in carbon equivalent emissions at the lowest marginal cost.

INTRODUCTION

Policy options for reducing greenhouse emissions may be evaluated in terms of an integrated budget of greenhouse gases. The purpose of this paper is to present a comprehensive approach that can account for the contributions to temperature change of all of the greenhouse gases, and provide policymakers with a meaningful measure by which to assess and compare the benefits of alternative policy packages for limiting greenhouse gas emissions. Although the reduction in growth or even stabilization of emissions would not stabilize atmospheric concentrations of the greenhouse gases, this framework provides a useful analytic tool and may be viewed as a first step towards the development of a comprehensive and meaningful policy.

Each of the many greenhouse gases has a different atmospheric residence profile (i.e., lifetime) and radiative forcing potential. These gases come from diverse sources, both natural and anthropogenic, including almost all economic sectors. Policymakers will find it difficult to compare reduction strategies which differ in the gases targeted. Unless a single metric is found by which to integrate the individual contributions to climate change of each of the gases, it will be difficult to assess the total impact of policy initiatives on global climate.

The comprehensive approach used in this analysis measures the emissions of each individual greenhouse gas in terms of a common metric: "carbon equivalents." Emissions are then summed to yield total current greenhouse gas emissions. Implementation of this approach is possible using values for the "Global Warming Potentials" of greenhouse gases recently published by the Intergovernmental Panel on Climate Change (IPCC).

Projections are also made of total emissions in the year 2000, given current U.S. commitments to environmental protection, coupled with assumptions about future U.S. environmental initiatives. These initiatives include the *America the Beautiful* tree planting program, the proposed amendments to the Clean Air Act, CFC phaseout and the Montreal Protocol, U.S. Department of Energy (DOE) energy efficiency initiatives, DOE renewables initiatives, DOE appliance standards, and a proposed EPA landfill regulation.

A comparison is made between what total emissions would have been in the absence of these current U.S. environmental commitments and what they are actually expected to be. This yields an estimate of the percentage reduction in carbon equivalents below what they would have been in 2000 had the U.S. not taken such initiatives.

To illustrate how the comprehensive approach can be used to evaluate additional policy initiatives to achieve further emissions reductions, a sample policy package consisting of three additional environmental initiatives has been examined. These initiatives include energy taxes, yet tighter landfill regulations, and a doubling of the *America the Beautiful* program. (They are drawn from a larger, diverse set of options, and therefore may not be the most cost-effective way to achieve these reductions.) This exercise illustrates how the comprehensive approach can be used to assess reductions in emissions of all greenhouse gases, and to evaluate policies intended to achieve carbon equivalent reductions throughout the U.S. economy.

Although this analysis does not answer the question of whether there is a global climate change "problem" and how large greenhouse gas emission reductions should be, it does identify an appropriate approach for integrating emissions of all gases into a single index, and for evaluating an integrated set of policy options intended to achieve emission reductions of all greenhouse gases in an efficient, least-cost manner.

CREATING AN INTEGRATED GREENHOUSE GAS INDEX

The scientific community has historically measured contributions to radiative forcing using estimated changes in *atmospheric concentrations*. However, when discussing the various greenhouse gases in a policy context, there is often a need for policymakers to have some means of describing the relative abilities of *emissions* of each greenhouse gas to affect radiative forcing, and hence climate, without the complex, time-consuming task of determining the impacts on atmospheric concentrations.[1] An index that translates the level of emissions (i.e., actual tonnage) of the various greenhouse gases into a common metric must be derived in order to compare the climate-forcing effects of the gases. This is the approach taken in this study.[2] Such an index permits a comparison of the changes in radiative forcing which arise from increases in the concentrations of radiatively active greenhouse gases in the troposphere and stratosphere. These include the direct effects due to growing concentrations of carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O). In addition, the index permits a consideration of the indirect effects on radiative forcing that can result from molecules that may not themselves be greenhouse gases, but which lead to chemical reactions which create greenhouse gases. These include volatile organic compounds (VOCs), nitrogen oxides (NO_x), and carbon monoxide (CO) -- all of which contribute to the formation of tropospheric ozone.

The index is called the Global Warming Potential (GWP). There is no universally accepted methodology for combining all the relevant factors into a single global warming potential for greenhouse gas emissions. The GWP of an individual greenhouse gas depends on its absorptive strength within the infrared spectrum, the relative concentrations of all greenhouse gases, its longevity and decay profile in the atmosphere, the time period over which the climate effects are of concern, and the relative weight placed on effects at different times. As noted in the draft IPCC Science Report (1990), the development of an index is still at an early stage, but progress has been made and preliminary values derived (see, for example, Derwent [1990], Fisher et al. [1990], Rodhe [1990], and Lashof and Ahuja [1990]).

For the purposes of this study (and following the methodology used in the draft IPCC Science Report), the concept of global warming potentials is based on a comparison of the radiative forcing effect over a period of time of the concurrent emission into the atmosphere of an equal quantity of CO_2 and another greenhouse gas. Each gas has a different instantaneous radiative forcing effect. In addition, the atmospheric concentration of each gas decays with

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[1] Theoretically, if emissions were generated whose net effect was no change in atmospheric concentrations, the net contribution to radiative forcing would be zero.

[2] Throughout this document, "tonnes" refer to metric tonnes, and "tons" refer to short tons.

time. In general, other greenhouse gases have a much stronger instantaneous radiative forcing effect than does CO_2; however, CO_2 has a longer atmospheric lifetime and a slower decay rate than the other greenhouse gases. Atmospheric concentrations of certain greenhouse gases may decline due to atmospheric chemical processes, which in turn create other greenhouse gases or contribute to their creation or longevity. These indirect effects are included in each gas' GWP.

Following this convention, the GWP is defined as the time integrated commitment to climate forcing from the instantaneous release of 1kg of a trace gas expressed relative to that from 1kg of carbon dioxide. This technique for measuring the GWP is, however, sensitive to the time horizon over which the analysis is conducted (i.e., the time period over which the integral is calculated), as illustrated in Figures 1 and 2. Figure 1 depicts the incremental radiative forcing effects of N_2O and CH_4, assuming a 100 year horizon. Figure 2 depicts the incremental radiative forcing effects of the two gases, assuming a 500 year horizon.

The emissions forecasts presented in this report are based on a GWP of 100 years. Table 1 summarizes the relative radiative forcing factors (GWPs) of key greenhouse gases (assuming both a 20 year and 100 year time horizon).[3]

A careful interpretation of the GWPs must be made when conducting policy analyses. For policy purposes, the relative importance of the different greenhouse gases depends on projected levels of emissions, their total atmospheric concentration at any point in time, as well as on their respective global warming potentials. One cannot conclude, for example, that CO_2 is the most important greenhouse gas over the long run simply because of its long lifetime and large current atmospheric concentration. Similarly, it is incorrect to conclude that in the short run, policy instruments designed to reduce emissions of methane, tropospheric ozone, and gases that contribute to the formation of greenhouse gases (e.g., CO, NO_x, VOCs) are more important than CO_2 because of their relatively high GWP values. Careful attention is therefore given in the next section to defining the assumptions underlying forecasts of future greenhouse gas emissions.

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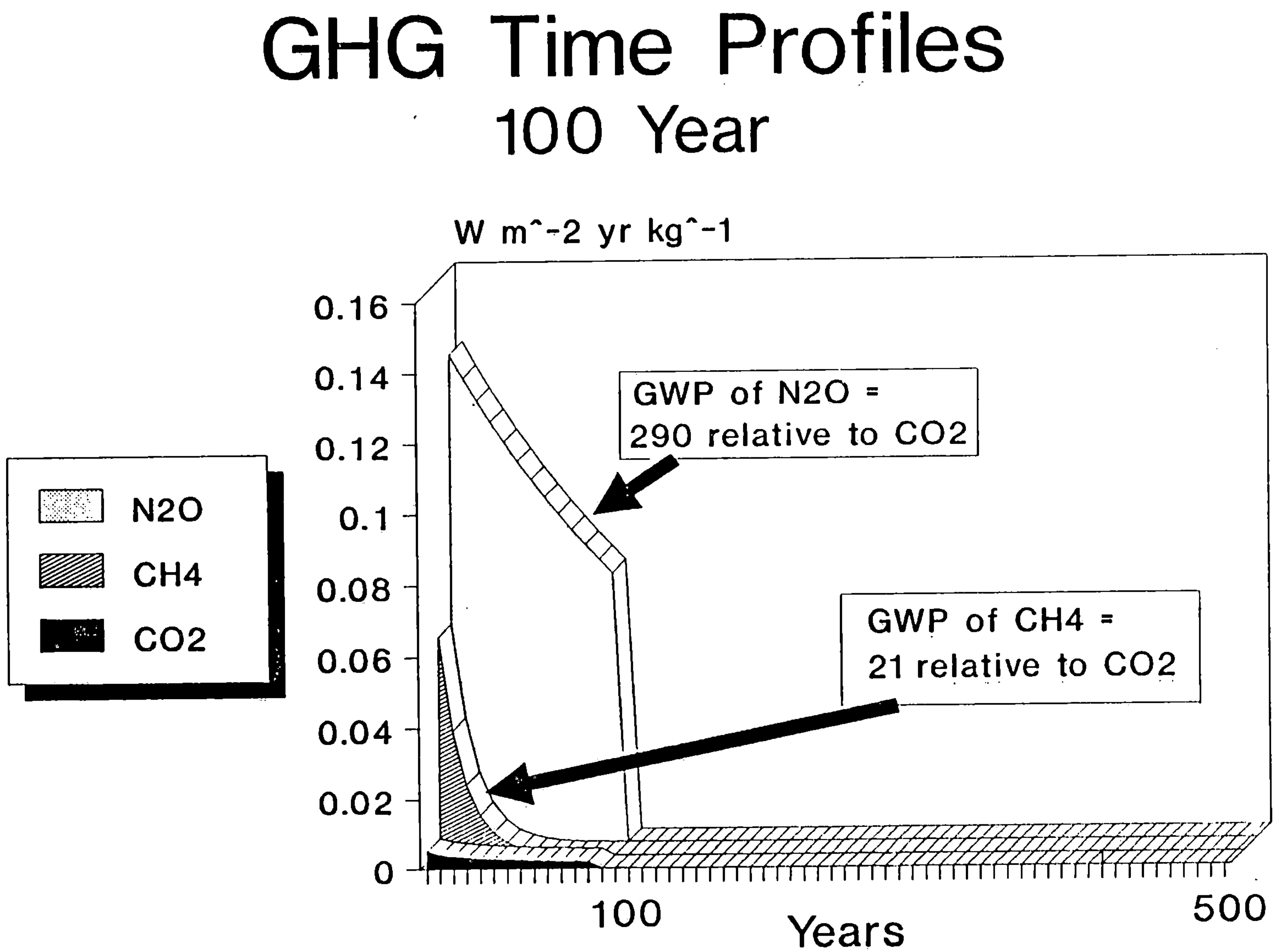
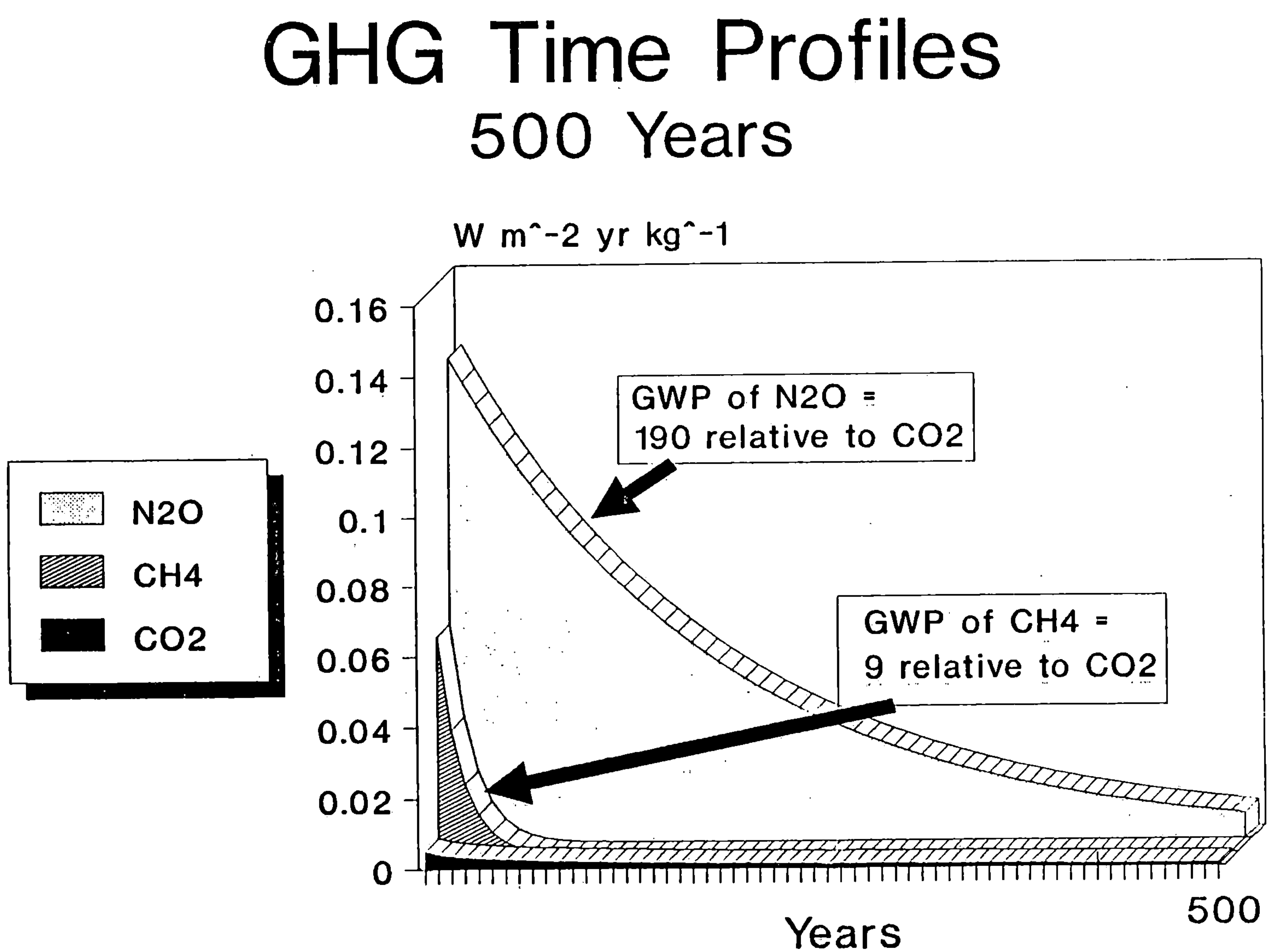
[3] In this analysis, it is assumed that the methane from landfills is flared, and thus converted into CO_2. Only partial credit can be taken for the CH_4 emission reduction. A GWP of 18 was used for methane reductions. According to the IPCC, the GWP for CH_4 on a weight basis, including both direct and indirect effects, is 21. This assumes a 100 year time horizon. In the landfill calculations, it was assumed that methane is flared and converted into CO_2. The CO_2 from methane has a GWP of 3 (for a 100 year time horizon). Credit for the emissions reductions was approximated by subtracting the GWP of 3 for CO_2 from the GWP of 21 for methane, yielding the GWP of 18. Similarly, emissions of carbon monoxide in the transportation sector are converted into CO_2. In the CO calculations for the transportation sector, it was assumed that CO is instantaneously converted into CO_2 in a catalytic converter. This CO_2 has a GWP of 2. Credit for the other indirect effects avoided (i.e., the impact of CO on tropospheric ozone, GWP=1) was approximated with a GWP of 1.



Radiative forcing of a gas is expressed as a change in the flux of energy, i.e., watts per sq. meter per kg of gas.

FIGURE 1



Radiative forcing of a gas is expressed as a change in the flux of energy, i.e., watts per sq. meter per kg of gas.

FIGURE 2

GLOBAL WARMING POTENTIALS

GAS	LIFETIME (years)	INSTANTANEOUS RADIATIVE FORCING (relative to CO_2)	POTENCY OVER 20 YEARS (relative to CO_2)	POTENCY OVER 100 YEARS (relative to CO_2)
CO2	120	1	1	1
METHANE	10	58	63	21
CFCs	7-200	1640-5800	1500-7100	430-7300
NITROUS OXIDES	150	206	270	290
OZONE	1	1600	207	57

SOURCE: IPCC draft Science Report

TABLE 1

CURRENT ENVIRONMENTAL COMMITMENTS ASSUMED IN THE ANALYSIS

Projections of future emissions of greenhouse gases must account for current commitments to environmental protection that will affect greenhouse gas emissions, as well as potential future initiatives. We present here a brief summary of the current U.S. environmental commitments accounted for in this study. Table 2 presents the carbon equivalent emissions reductions expected in 2000 due to these initiatives. A more detailed documentation of the sources for the emissions estimates used in the analysis, as well as underlying assumptions, is contained in the Appendix.

Tree Initiative

The *America the Beautiful* reforestation initiative (currently under consideration by Congress) set a goal of planting one billion trees per year on 1.5 million acres, for ten to twenty years beginning in 1991, and to improve forest management practices on an additional 100,000 acres per year. The total program could sequester approximately 50 million tons of carbon per year by the year 2010, or between 4-5 percent of current net U.S. CO_2 emissions of carbon.

Reforestation options differ from other emissions reduction or sequestration options because of: (i) the long time frames required for both planting and growing trees (10 years to plant large acreages, and 30 years to grow to maturity), and (ii) the nonlinear shape of the carbon benefit curve, with only small offset potential in near-term years, but large potential in later years once all trees are planted and have grown. The program is targeted to first utilize low-productivity, economically marginal or environmentally sensitive lands (i.e., lands with low opportunity costs), and then attract more expensive lands in later stages.

TABLE 2

EMISSIONS REDUCTIONS EXPECTED IN THE YEAR 2000 DUE TO CURRENT ENVIRONMENTAL COMMITMENTS AND OTHER INITIATIVES ASSUMED IN THE ANALYSIS

CURRENT COMMITMENTS	**MILLIONS OF TONNES REDUCED (Carbon Equivalents) 2000**[4]
o TREE INITIATIVE	~9
o DOE ENERGY EFFICIENCY INITIATIVES	28
o DOE APPLIANCE STANDARDS	4
o DOE RENEWABLE INITIATIVES	4
o CLEAN AIR ACT	17
o LANDFILL REGULATION	44
o CFC PHASEOUT & MONTREAL PROTOCOL	551

[4] Assumes a 100 year time horizon in GWP calculations.

The following estimates have been made of the CO_2 offset benefits and costs for U.S. reforestation initiative options (Moulton *et al.*, 1990):

% Offset (in 2030) of U.S. CO_2 Emissions	**Million Tons C (2000)**	**Million Tons C (2030)**	**Total Annual Program Cost (2000)[5]**
5	9	55-69	$545 mill.
10	18	110-138	$1.4 bill.
20	36	220-276	$3.7 bill.

DOE Energy Efficiency Initiatives, Renewable Initiatives, and Appliance Standards

The DOE energy efficiency initiatives include more efficient lighting in Federal and commercial buildings, promotion of state least-cost utility planning, state adoption of interim building standards, energy analysis and diagnostic centers, and HUD adoption of DOE building standards. Also included are DOE renewable initiatives, including expanded use of hydroelectric power and the transfer of photovoltaic technology.

Estimates of reductions in the year 2000 due to these initiatives were taken from numbers provided by DOE. Estimates of reductions in the year 2000 due to the renewable initiatives are also taken from data provided by DOE, except that expanded hydropower capacity was assumed to produce only half of the reduction estimated by DOE.

Revised DOE appliance standards apply to refrigerators and freezers, washers, dryers, and dishwashers. Estimates of reductions in the year 2000 due to revised standards for these four appliance groups were taken from DOE Technical Support Documents published as part of the rulemaking process.

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[5] These estimates are based on amortized costs over 40 years, discounted at a 10 percent real rate. It is assumed that it will take 10 years to plant the trees, beginning in 1990, and 30 years for the trees to grow to maturity in 2030. The range of carbon sequestration given assumes current sequestration rates of existing seedling stock (low estimate). An average carbon sequestration of 1.8-2.2 tons carbon per acre per year is assumed, varying by site index (growth conditions for appropriate species).

These data are summarized in Table 3. Further documentation of the sources for these estimates and underlying assumptions is contained in the Appendix.

Clean Air Act

The new Clean Air Act initiative will result in emission reductions for CO_2, NO_x, CO, and VOCs, as well as other criteria air pollutants.[6] NO_x reductions are projected to come from controls on motor vehicles, utilities, non-utility point sources, and area sources. VOC reductions are expected to come from control on motor vehicles. Reductions in CO are expected to come from automobile fleet turnover, the cold temperature rule, and an oxygenated fuels program. Estimates of CO_2 emissions reductions in the year 2000 were taken from data provided by DOE (and summarized in Table 3).

To be consistent with EPA national air pollutant emission estimates (EPA, 1989), N_2O emissions rates are projected to remain unchanged through 2000.

Landfill Regulation

There are approximately 6000 active landfills in the United States. Most landfills are relatively small (i.e., 70 percent contain less than one million tons). Landfills are "bioreactors" that generate 255,000 Mg/yr of non-methane organic emissions, as well as 10.5 million Mg/yr of methane.

Landfill control includes (i) collection of landfill gases by wells, and (ii) combustion or recovery of these gases. In this analysis, it is assumed that the methane from landfills is flared and converted into CO_2.

The proposed landfill regulation results in approximately a 9 million tonne reduction in methane in 2000.

CFC Phase out & Montreal Protocol

On January 1, 1989, the "Montreal Protocol on Substances That Deplete the Ozone Layer" (or the Montreal Protocol) came into force. The major provisions of the Protocol affecting U.S. emissions include a 50% reduction from 1986 levels in the use of CFC-11, -12, -113, -114, and -115 by 1998, and a freeze on the use of Halon 1211, 1301, and 2402 at 1986 levels starting in approximately 1992.

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[6] For this analysis, the Senate version of the Clean Air Act is assumed.

DOE-RELATED CO_2 EMISSIONS REDUCTIONS USED IN EPA'S GHG EMISSIONS INVENTORY

ACTION/PROGRAM	2000	
	CO_2	Carbon
DOE Appliance Standards (Refrigerators, Washers, Dryers, Dishwashers)	**16.0**	**4.4**
DOE Efficiency Initiatives	**102.0**	**27.8**
Federal Buildings Lighting	5.0	1.4
Commercial Buildings Lighting	9.0	2.5
Promote State LCUP	33.0	9.0
State Adoption of Interim Building Standards	30.0	8.2
Energy Analysis and Diagnostic Centers	22.0	6.0
HUD Adoption of DOE Building Standards	3.0	0.8
DOE Renewable Initiatives	**15.0**	**4.1**
Expanded Hydro Power	13.0	3.5
Photovoltaic Technology Transfer	2.0	0.5
Clean Air Act	**63.0**	**17.2** *
Acid Rain	60.0	16.4
Transportation Biofuels and Natural Gas Use	3.0	0.8
GRAND TOTAL	196.0	53.5

* Does not include reductions of 51 million metric tonnes due to decreases in NO_x (19.6 million tonnes), CO (7.4), and VOCs (23.7).

TABLE 3

A possible phase out of controlled CFCs and halons by 2000 is being considered by the U.S. and several other countries. This would eliminate 95 percent of the radiative forcing due to CFC emissions (in 2000).

The CFCs included in this study are CFC-11, -12, -113, -114, HCFC-22, CCl_4, HCFC-134, HCFC-141b, and HCFC-124.

EMISSIONS PROJECTIONS

Emissions Given Current Environmental Commitments

Figure 3 depicts EPA estimates of the current status of emissions of greenhouse gases. Total U.S. greenhouse gas emissions, expressed in terms of carbon equivalents, are 2328 million metric tonnes. CO_2 emissions account for 56 percent of total U.S. greenhouse gas emissions.

Figure 4 depicts EPA estimates of projected emissions in the year 2000, given current commitments to environmental protection. Each estimate depends on an underlying assumption about growth in economic activity. In general, year 2000 emissions would be higher if the economy grew faster. Each estimate is also sensitive to other key influences, such as oil prices. Analysis using the comprehensive approach reveals that total U.S. greenhouse gas emissions in 2000 will be equivalent to 2332 million tonnes of carbon.

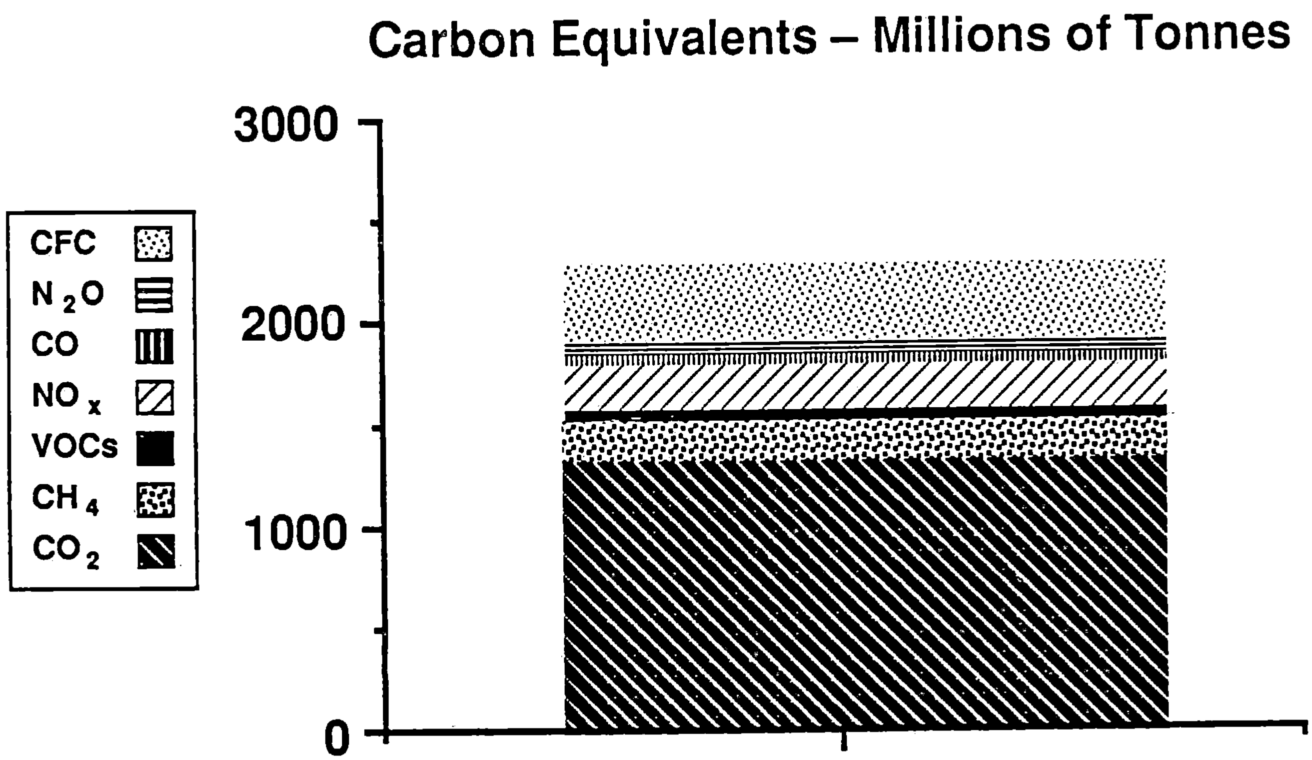
A comparison of emissions in 1987 with those in 2000 reveals ***total emissions in the year 2000 will be held to 1987 levels***. (This does not imply, however, that total emissions will be stabilized at 1987 levels beyond the year 2000.) The difference between emissions in 1987 and 2000 is 4 million metric tonnes of carbon equivalent (within the range of uncertainty of the estimates). (If only direct CO_2 emissions are considered, CO_2 emissions in 2000 will still be about 15 percent higher than 1987 levels.) If CFCs are not included in the total greenhouse gas budget, total emissions in the year 2000 will exceed 1987 levels by 115 million tonnes of carbon equivalents.

Conclusion: **Analysis reveals that given current environmental commitments, coupled with additional possible environmental initiatives, the U.S. contribution to the total budget of greenhouse gases will be held at 1987 levels in the year 2000 (if CFCs are included in the total greenhouse gas budget). This result is sensitive to underlying assumptions about economic growth and other key factors, such as oil prices.**

Table 4 provides information on the percentage contribution to global warming potential of U.S. emissions of key individual greenhouse gases included in this study. Individual contributions are calculated by multiplying emission levels by GWPs. Percentages are calculated for current (1987) U.S. emissions as estimated by EPA, and for projected emissions in the year 2000, accounting for current U.S. environmental commitments and possible additional

Current Emissions 1987

(100 Year GWP Factors)

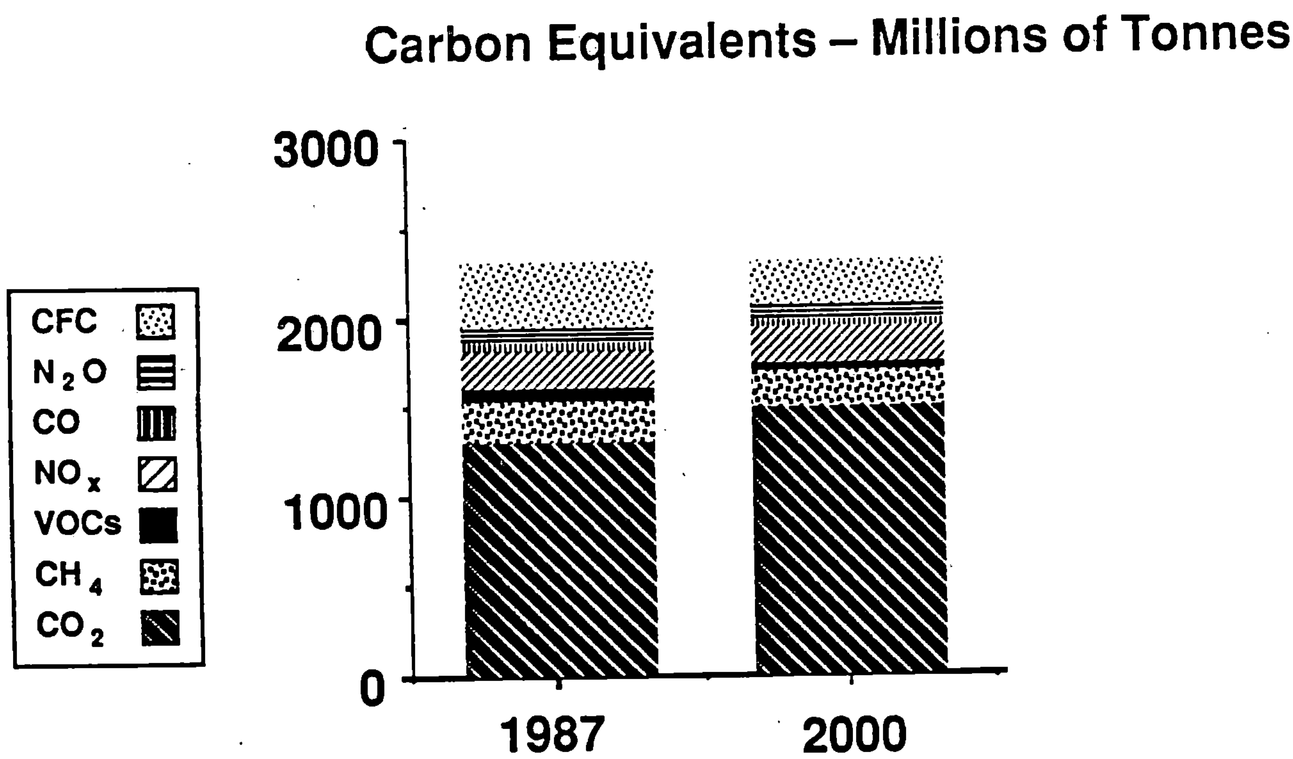


	1987
CO_2	1310
CH_4	235
VOCs	72
NO_x	218
CO	52
N_2O	74
CFC	367
Total	2328

FIGURE 3

Emissions

(With Current Commitments)
(100 Year GWP Factors)



	1987	2000
CO_2	1310	1503
CH_4	234	208
VOCs	72	48
NO_x	218	199
CO	52	45
N_2O	74	74
CFC	367	256
Total	2328	2332

FIGURE 4

environmental initiatives. For the purposes of comparison, percentages for worldwide emissions are also calculated for 1990, based upon IPCC emission projections.

TABLE 4

PERCENTAGE CONTRIBUTION TO GLOBAL WARMING POTENTIAL OF INDIVIDUAL GASES (100 GWP)

	U.S. Emissions		Worldwide Emissions
GAS	EPA 1987	EPA 2000 (w/commitments)	IPCC 1990
CO_2	56	64	61
CH_4	10	9	15
N_2O	3	3	4
CO	2	2	1
NO_x	9	9	6
CFC-11	2	2	2
CFC-12	9	6	7
CFC-113	1.1	2.6	0.4
CFC-114	2.8	0	1.5
HCFC-22	0.4	0	0.2
CCl_4	0.4	0.2	0.3

Emissions in the Absence of Current Environmental Commitments

It is instructive to forecast what emissions *would have been* in the year 2000, had current commitments not been made by the U.S.[7] These projections are presented in Figure 5. A comparison of Figures 4 and 5 reveals that current U.S. environmental commitments, coupled with additional possible initiatives, will yield a 24 percent reduction in carbon equivalent emissions below what they would have been in 2000.

A close examination of U.S. emission trends in the individual greenhouse gases reveals the importance of CFC phaseout and the Montreal Protocol. The total contribution of CFCs to the greenhouse budget in 1987 was 367 million tonnes of carbon. In the absence of the Montreal Protocol and CFC phaseout, emissions of this gas would grow to 807 million tonnes of carbon. With current commitments to phaseout, emissions of CFCs will decline to 256 million tonnes of carbon by 2000.

Conclusion: **Analysis reveals that current U.S. environmental commitments, coupled with additional possible initiatives, yields a 24 percent emissions reduction below what they would have been in the absence of these U.S. actions.**

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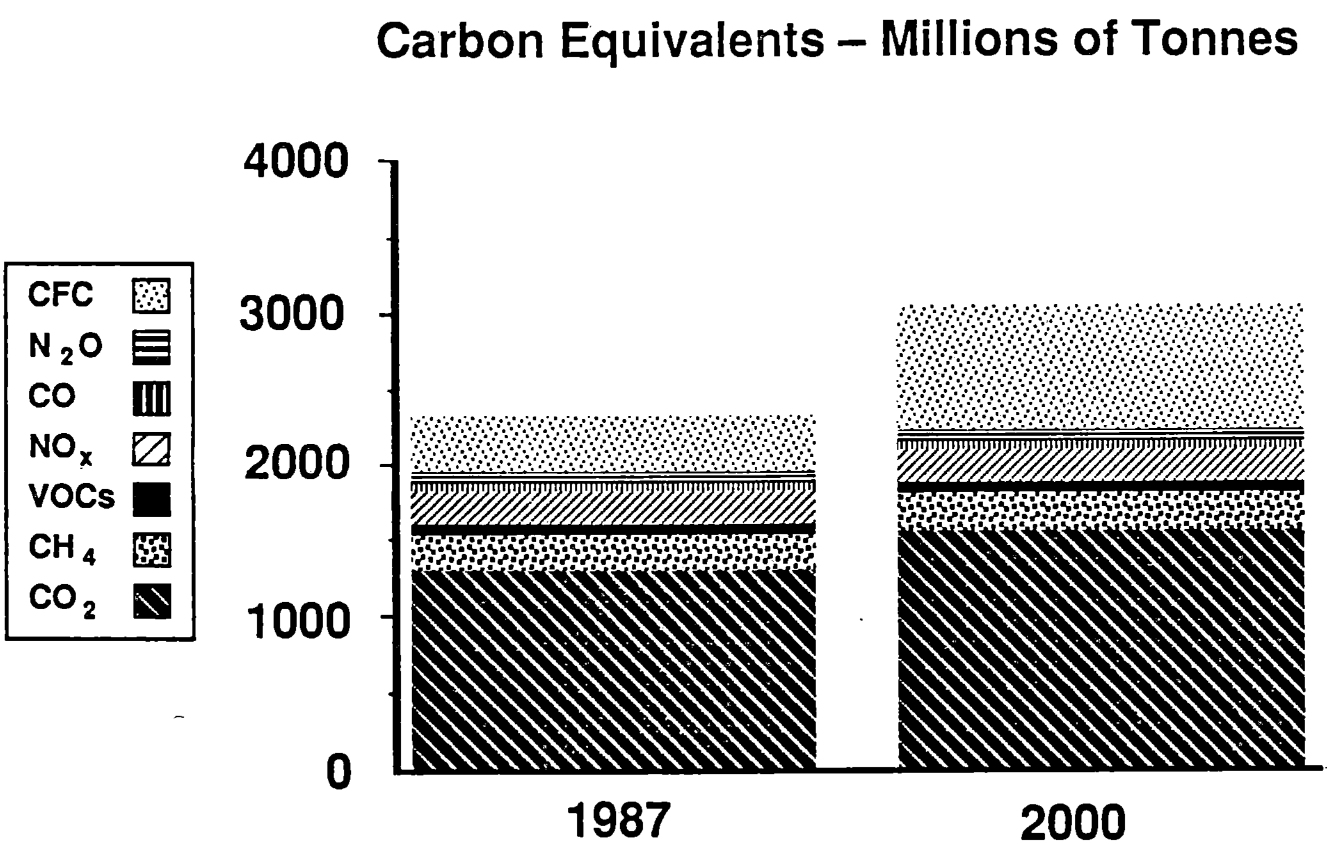
[7] Credit is only being taken for the contributions from these initiatives from 1987 forward.

Emissions
(Without Current Commitments)
(100 Year GWP Factors)



	1987	2000
CO_2	1310	1565
CH_4	235	252
VOCs	72	72
NO_x	218	218
CO	52	52
N_2O	74	74
CFC	367	807
Total	2328	3040

FIGURE 5

ADDITIONAL POLICY INITIATIVES

EPA has investigated additional policy options that could hold the greenhouse gas emissions index in the year 2000 at 1987 levels, and help maintain this emissions rate beyond 2000. This analysis included tax and nontax initiatives.

TAX INITIATIVES

Two sets of tax-based policy options were considered for reducing CO_2 emissions. The first set of options consist of transportation taxes: a federal gasoline tax, and an oil import fee. The second set of taxes consist of general carbon taxes on fossil fuels. Estimates were made of total annual carbon reductions in the year 2000, annual tax revenues, and the change in GNP.

Transportation Taxes

To estimate the effects of a federal gasoline tax and an oil import fee, the Data Resources Incorporated (DRI) Transportation model was employed.[8] In both cases, it was assumed that the taxes were phased in over time.

Results for the transportation taxes are presented in Table 5. A $0.33/gallon tax on gasoline (equivalent to a $120/ton carbon tax) would reduce emissions of carbon by 16 million tonnes, which is more than sufficient to ensure that total emissions will be held at 1987 levels in the year 2000. The total effect on GNP would be a 0.3 percent annual decrease. To the extent that GNP is a measure of social welfare, this suggests that society will be worse off by 0.3 percent per year. It is important to note, however, that this GNP measure does not capture the social benefits (e.g., due to environmental protection) that accrue from the carbon reductions.

A phased-in oil import fee of $6.00/barrel would also yield significant carbon reductions of 30 million tonnes per year, at a cost to society of a 0.6 percent annual reduction in GNP.

Both transportation taxes yield significant annual tax revenues. The $0.33/gal. gasoline tax would yield $35 billion of revenues, while the import fee would yield $23 billion in tax revenues.

[8] The results presented here are preliminary DRI model estimates.

TRANSPORTATION TAXES

FOR THE YEAR 2000

(all numbers in constant 1989 dollars)

	Annual Revenues (Bill. $'s)	Carbon Reductions (Mill. tons)	GNP Change (Percent)	Comments
Gasoline Tax (Phased-in)				
$0.33/Gal. ($120/ton carbon)	35	18	-0.3	DRI interim results
$1.24/Gal ($452/ton carbon)	103	86	-2.0	DRI interim results
Oil Import Fee (Phased-in)				
$6.00/Barrel ($50/ton carbon)	23	33	-0.6	DRI interim results

TABLE 5

Carbon Taxes

Three models were used to estimate the effects of carbon taxes: the Manne-Richels *Global 2100* model, the Dynamic General Equilibrium Model (DGEM) developed by Dale Jorgenson (Harvard), and the DRI national energy model. A range of taxes were examined, from $5.00/ton carbon to $25.00/ton.[9] (Using the DRI model, estimates were also made of the gasoline tax that would yield similar impacts as each carbon tax.)

Results for the three models are presented in Table 6. The Manne-Richels model suggests that a carbon tax will generally be less efficacious in achieving carbon reductions than is suggested by either the DRI or DGEM models. Manne-Richels suggest that a $5/ton tax will result in approximately a 9 million tonne reduction in carbon, as compared to the 25 million tonne reduction predicted by DRI and a 62 million tonne reduction forecast by DGEM. Nevertheless, this $5/ton tax is sufficient to achieve the 4 million tonne reduction in carbon emissions necessary to hold year 2000 emissions at 1987 levels.

Results from the DGEM model suggest that the long-run GNP effects of a carbon tax will be small. DGEM results suggest that a $25/ton carbon tax will result in "only" a 0.2 percent annual decrease in GNP. Manne and Richels have also estimated that the projected GNP loss associated with a $5/ton carbon tax would be "negligible," assuming that increased taxes are employed for deficit reduction, and that this in turn will stimulate private investment.

It is important to note, however, that the short-run fluctuations in GNP forecast by the models differ dramatically because of structural differences in the models. As reported in Montgomery (1990), the DRI model projects much larger short-run effects of a CO_2 charge due to higher energy prices that stimulate a wage-price spiral. In the long-run, however, reduced interest rates lead to higher investment and significant improvement in GNP growth. In contrast, the immediate impact shown in the DGEM model occurs simply because the model ignores short-term difficulties in adjustment, focusing on long-run responses.

A comparison can be made of the effects of the transportation and carbon taxes (as estimated by the DRI models). A $5.00 per ton carbon tax is equivalent to a 1 cent/gal. gasoline tax. Yet, the carbon tax will yield 25 million tonnes of carbon emissions reductions, whereas a $0.33/gal. gasoline tax will only yield 16 million tonnes of carbon reductions. This result is not surprising given the multi-sectoral impacts of a carbon tax (which is imposed on all fossil fuels), as opposed to the gasoline tax which only affects the transportation sector.

It is important to note that distributional and equity issues have not yet been examined. For example, a carbon tax on fossil fuels will likely have significant impacts on the levels of output and employment in the coal industry, which are not captured in this analysis. Further, a carbon tax unilaterally imposed on U.S. production may lead to an "exportation" of energy-

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[9] A thorough description and comparison of these models is contained in Montgomery (March 1990).

ENERGY TAXES

Carbon Tax per ton	Annual Revenues 2000 (Bill. $)	Carbon Reductions (Mill. tons)	GNP Change (Percent)	Comments
Manne-Richels				
$5.00	7	10	not available	Provided to EPA by authors
$10.00	14	20	not available	
$15.00	20	30	not available	
DRI				
$5.00 (1 cent/gal.)	8	27	not available	GNP losses likely to be larger than Manne-Richels or Jorgenson Interpolated by EPA
$10.00 (3 cent/gal.)	11	54	not available	
$15.00 (4 cent/gal.)	23	82	not available	
$25.00 (6 cent/gal.)	38	136	not available	
Jorgenson				
$5.00	10	68	0.1	Interpolated by EPA
$10.00	14	136	0.1	
$15.00	30	200	0.2	
$25.00	50	272	0.2	

TABLE 6

intensive production to other countries. Such a shift may lead to increased carbon emissions in other countries, offsetting the benefits gained from the tax in the U.S.

NONTAX INITIATIVES

Several potential nontax initiatives have also been examined that could yield significant additional carbon reductions by the year 2000. These include tighter landfill regulations and the planting of more trees. These initiatives are summarized in Table 7. Several other energy sector options that are currently under investigation by EPA are presented as illustrations of alternative sources for emissions reductions.

If regulations to limit methane emissions from landfills were tightened beyond pending EPA regulations, an additional 39 million tonne reduction in carbon equivalent emissions could be achieved, at an annual cost of $431 million dollars. If the *America the Beautiful* commitment were doubled, so that an additional one billion trees were planted per year, an additional reduction of 9 million tonnes of carbon could be attained at an annual cost of $850 million.

The results for these case studies are presented to illustrate: (i) how the comprehensive approach can be used to assess reductions in emissions of all greenhouse gases, and to evaluate policies intended to achieve carbon equivalent reductions throughout the U.S. economy; (ii) that a diversity of sources exist from which reductions in greenhouse gas emissions can be achieved; and (iii) that many of these are cost-effective or low-cost options. No attempt, however, has been made in this analysis to measure the *net benefits* of any particular package of policy options.

POTENTIAL NONTAX INITIATIVES -- 2000

	CARBON TONNES REDUCED	ANNUAL COSTS (millions)	COMMENTS
TIGHTER LANDFILL REGULATION	39	$431	Tighten beyond pending EPA regulations
MORE TREES	9	$850	Double *America the Beautiful* commitment
Energy Sector Options			
• UTILITY-BASED INCENTIVE PROGRAMS	?	?	Provide incentives for use of cost-effective energy-saving technologies in residential sector; beyond currently proposed DOE standards.
• COMMERCIAL LIGHTING & FAN MOTOR STANDARDS	?	?	Technologies not currently covered by DOE standards.
• BIOMASS ELECTRICITY PROJECT	?	?	Short-rotation biomass and ISTIG demonstration programs.

TABLE 7

CONCLUSIONS

Several major conclusions emerge from this study:

- In the evaluation of policy options for reducing greenhouse emissions, it is necessary to assess an integrated budget of all greenhouse gases. A comprehensive approach has been developed that accounts for the differences in atmospheric lifetimes and radiative forcing effects of greenhouse gases (including those gases which through chemical interactions affect concentrations of direct greenhouse gases), and expresses emissions of each greenhouse gas in terms of a common metric ("carbon equivalents"). Emissions of all greenhouse gases can then be integrated into an overall greenhouse gas budget.

- An assessment of current (1987) emissions using the comprehensive approach indicates that total U.S. greenhouse gas emissions, expressed in terms of carbon equivalents, are 2328 million tonnes (assuming a 100 year Global Warming Potential [GWP]). CO_2 emissions account for 56 percent of total U.S. greenhouse gas emissions.

- Given current U.S. environmental commitments, and assumptions made regarding growth in economic activity and energy price developments, coupled with additional environmental initiatives, total emissions (as opposed to atmospheric concentrations) will be held at 1987 levels in the year 2000. (This does not imply, however, that total emissions will be stabilized at 1987 levels beyond the year 2000.) Analysis using the comprehensive approach reveals that total greenhouse gas emissions in 2000 would be equivalent to 2332 million tonnes of carbon. (Direct CO_2 emissions will still be about 15 percent higher than 1987 levels.)

- These environmental commitments, coupled with additional initiatives, will yield a 24 percent reduction in carbon equivalent emissions below what they otherwise would have been in 2000 in the absence of such initiatives. The programs accounting for this reduction include the Montreal Protocol and CFC phaseout, the Clean Air Act, DOE initiatives, the *America the Beautiful* tree planting program, and pending EPA landfill controls.

- A close examination of emissions trends in the individual greenhouse gases reveals the importance of the Montreal Protocol and CFC phaseout. The total contribution of CFCs to the greenhouse budget in 1987 was 367 million tonnes of carbon equivalents. It is estimated that in the absence of the Montreal Protocol and CFC phaseout, emissions of this gas would grow to 807 million tonnes of carbon equivalents. With current commitments to phaseout, emissions of CFCs will decline to 256 million tonnes of carbon equivalents by 2000.

- The comprehensive assessment approach reveals that three additional policy initiatives can ensure that emissions will be held to 1987 levels in the year 2000. These initiatives include energy taxes, yet tighter landfill regulations, and a doubling of the *America the Beautiful* tree planting program.

These results have important implications for the formulation of both domestic and international policies to reduce greenhouse gas emissions. First, it suggests the importance of considering greenhouse gases other than just CO_2. The comprehensive approach used here enables one to focus on the diverse sources of greenhouse gases other than just those that emit CO_2. (This will also help ensure that an undue burden is not placed on those industries that emit CO_2, such as those that are energy intensive and burn fossil fuels.) Many opportunities exist for achieving carbon equivalent reductions throughout the U.S. economy.

Finally, the comprehensive approach enables the U.S. and other countries to achieve greenhouse gas emissions reductions in a least-cost manner. It permits a country to achieve those reductions through limits on emissions of a diversity of greenhouse gases, some of which may be cheaper to control than others. Countries will be able to achieve incremental reductions in carbon equivalent emissions at the lowest marginal cost.

APPENDIX

SOURCES OF GREENHOUSE GAS EMISSIONS ESTIMATES

The following appendix documents the sources of the emissions estimates for each of the greenhouse gases, as well as important underlying assumptions. Documentation is presented for: (i) the 1987 "base case," (ii) emissions in 2000 without current environmental commitments, and (iii) emissions in 2000 with current environmental commitments.

CO_2:

Estimates of CO_2 emissions for 1987 and 2000 (without current environmental commitments) were derived from figures provided by the U.S. Department of Energy (DOE) to the Energy and Industry Subgroup (EIS) of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change (IPCC).

CO_2 emissions reductions in the year 2000 were estimated by DOE for the following current environmental commitments:

- **DOE Energy Efficiency Initiatives**
- **DOE Appliance Standards**
- **DOE Renewable Initiatives**
- **Proposed Clean Air Act Legislation and DOE Transportation Fuels Program**

A detailed discussion of each of these initiatives follows:

I. **DOE Energy Efficiency Initiatives (102 million tons CO_2)**

- **More Efficient Lighting in Federal Buildings (5 million tons CO_2)**

  It is assumed that federal agencies fully comply with the relevant Executive Order by 2000. Electricity savings would be 0.05 quad.

* **More Efficient Lighting in Commercial Buildings (9 million tons CO_2)**

It is assumed that approximately one-half of buildings convert to high efficiency lighting with an average savings of 25 percent of electrical demand for lighting. Electricity savings are 0.125 quad.

* **Promotion of State Efforts to Institute Utility Integrated Resource Planning for End-use Energy Efficiency (33 million tons CO_2)**

This and CO_2 reductions from the Clean Air Amendments are linked. Many states are emphasizing Integrated Resource Planning, although methods of analysis and implementation plans are not fully developed for all states. Due to the impetus for Clean Air Act legislation, the need for coal/fossil fuel generation may be reduced by 10-15 percent due to demand reduction. Supporting DOE programs would primarily include methods development and promotional options. Hence, reductions by the year 2000 would probably be lower than would otherwise be achieved. A 7.5 percent reduction in added demand is assumed, resulting in an electricity savings of 0.48 quad.

* **Adoption of DOE Interim Building Standards by the States (30 million tons CO_2)**

The DOE program includes dissemination of information and provision of voluntary guidelines. States could transform the guidelines into enforceable standards. Federal buildings must meet new standards beginning in 1989. It is assumed that there would be a 50 percent acceptance rate for new non-Federal buildings and a 20 percent demand reduction per building. Savings would be .43 quads of electricity.

* **Expansion of the Energy Analysis and Diagnostic Centers to Increase Energy Audits (22 million tons CO_2)**

Program expansion would occur to 40 energy efficiency engineering centers by 2000, resulting in audits of 3 percent of eligible industrial facilities by 2000. The estimate assumes implementation of 60 percent of audit recommendations, with a 15 percent improvement in energy efficiency. Total savings of all fuels would be .28 quads, including .05 quads of electricity.

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United States Department of Energy
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