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GREENHOUSE GAS EMISSIONS AND THE DEVELOPING COUNTRIES: STRATEGIC OPTIONS AND THE U.S.A.I.D. RESPONSE

A Report to Congress

July 1990

U.S. Agency for International Development
Washington, DC

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AGENCY FOR INTERNATIONAL DEVELOPMENT

320 TWENTY FIRST STREET, N.W.
WASHINGTON, D.C. 20523

July 31, 1990

The Administrator

The Honorable Robert C. Byrd
Chairman
Committee on Appropriations
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I am pleased to transmit the report of the Agency for International Development (A.I.D.) on climate change issues as requested in Section 534(c) of the Fiscal Year 1990 Foreign Assistance Appropriations Act.

The report discusses the main sources of greenhouse gas emissions (energy production, deforestation, and agriculture) and the countries and geographic regions from which these emissions emanate. The quantitative data on which this presentation is based were developed largely by the International Panel on Climate Change (IPCC), an intergovernmental effort.

The report discusses strategies which could and should be pursued to reduce greenhouse gas emissions, and it attempts to estimate the effect such strategies might have on reducing atmospheric concentrations of those gases. It should be emphasized that this is an area where there is still considerable uncertainty with respect to the quality of the data, the science, and the potential impacts of policy changes.

The report describes ongoing and planned A.I.D. activities concerned with climate change and also suggests possible new initiatives which will be further explored to determine their feasibility and efficacy.

Over the past year A.I.D. has made significant strides in addressing the global climate change issue. However, this report should not be considered a final, authoritative

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expression of the A.I.D. strategy. As we learn more about climate change--in terms of the science, policy, institutional and other aspects--our strategy will evolve further.

Sincerely,

Ronald W. Roskens

Enclosure:

GREENHOUSE GAS EMISSIONS AND THE
DEVELOPING COUNTRIES: STRATEGIC OPTIONS
AND THE U.S.A.I.D. RESPONSE

ACKNOWLEDGEMENTS

This report reflects the contributions of a number of people in A.I.D. and other agencies and organizations. The report has benefitted greatly from the support and involvement of the Environmental Protection Agency (EPA), especially of Paul Schwengels and Dennis Tirpak.

At A.I.D., principal contributions were made by David Jhirad, S. Padmanabhan, Jack Vanderryn, and Jerome Weingart. Robert Archer, Thurman Grove, Robert Ichord, Russell Misheloff, Sharon Pfeiffer, and Tony Pryor contributed useful input. Craig Ebert and Barbara Braatz of ICF, Inc. provided the data used in Chapters 2-4.

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LIST OF ABBREVIATIONS

AAGR	annual average growth rate
ACEEE	American Council for an Energy Efficient Economy
ADB	Asian Development Bank
AFBC	Atmospheric Fluidized Bed Combustion
AFOS	Agriculture, Forestry, and Other Human Activities Subgroup of the IPCC
A.I.D.	U.S. Agency for International Development
ANE	A.I.D. Bureau of Asia, Near East and Europe
APAP	Agricultural Policy Analysis Project
ASDG	Agricultural Sector Development Grant
ASEAN	Association of South East Asian Nations
BEC	Budapest Environmental Center
CARE	Concerned Americans for Relief Everywhere
CCl_4	carbon tetrachloride
CFC	chlorofluorocarbon
CGIAR	Consultative Group on International Agricultural Research
CH_3CCl_3	methylene chloride
CH_4	methane
CO_2	carbon dioxide
CO	carbon monoxide
CRSP	Collaborative Research Support Program
DESFIL	Development Strategies for Fragile Lands Project
DOE	U.S. Department of Energy
ECEP	Egypt Energy Conservation and Efficiency Project
EDM	Energy Demand Management
EEU	Energy Efficiency Unit
EIS	Energy and Industry Subgroup of the IPCC
EJ	exajoule = 10^{15} joules
EMCAT	Energy Management, Consultation, and Training Project
ENERCON	Pakistan National Energy Conservation Centre
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
F/FRED	Forestry/Fuelwood Research and Development Project
FAA	U.S. Federal Agricultural Administration
FAO	Food and Agricultural Organization of the United Nations
FLUP	Forest Land-Use Planning project sponsored by A.I.D.
FY	fiscal year

GCM	General Circulation Model
GDP	gross domestic product
GJ	gigajoule
GNP	gross national product
GOP	Government of Pakistan
GEEI	Global Energy Efficiency Initiative
GW	gigawatt
GWP	global warming potential
ha	hectare
HCFC	hydrochlorofluorocarbon
IBRD	International Bank for Reconstruction and Development
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICSU	International Council of Scientific Unions
IED/MEMR	Government of Jordan Industrial Energy Department of the Ministry of Energy and Mineral Resources
IFDC	International Fertilizer Development Center
IIEC	International Institute for Energy Conservation
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
kWh	kilowatt hour
LAC	A.I.D. Latin America and the Caribbean Bureau
LDC	Less Developed Country
LPG	liquified petroleum gas
MAGPI	Multi-Agency Working Group on Power Sector Innovation
MDh	Moroccan Dirhan
MMT	million metric tons
mt	metric tons
mtce	million tons coal equivalent
mtoe	million tons oil equivalent
MW	megawatt
N_2O	nitrous oxide
NAS	U.S. National Academy of Sciences
NFM	Natural Forest Management Techniques
NGO	non-governmental organization
NO_x	nitrogen oxides
NRMS	Natural Resource Management Support Project
OECD	Organization for Economic Cooperation and Development: U.S., Canada, Japan, and Western Europe

OEP	Egyptian Office for Energy Planning
PACER	Program for Acceleration of Commercial Energy Research
PC	Pulverized Coal
PFBC	Pressurized Fluidized Bed Combustion
Pg	petagram = 10^{15} grams
PNRM	Plan for Natural Resource Management
PSED	Private Sector Energy Development Program
PURPA	California Public Utilities Regulatory Policies Act of 1978
PVO	private voluntary organization
PV	photovoltaic
RE	Rural Electrification
ROCAP	A.I.D. Regional Office for Central America and Panama
Rs	Indian rupees (17 rupees ≈ $1 U.S.)
RSWG	Response Strategies Working Group of the IPCC
S & T	Science and Technology
SPSP	Small Project Support Project
STIG	steam-injected gas turbine
t	ton
TFAP	Tropical Forestry Action Plan
Tg	teragram = 10^{12} grams
TW	terawatt = 10^{12} watts
UNEP	United Nations Environment Programme (Nairobi, Kenya)
WMO	World Meteorological Organization (Geneva, Switzerland)
WRI	World Resources Institute (Washington, DC)

GLOSSARY OF TERMS*

Climate System

The interactive components of our planet that determine the climate. This includes the atmosphere, oceans, land surface, sea ice, snow, glaciers, and the biosphere. Climate change can be measured in terms of any part of the system, but it is most convenient to use surface air temperature as a measure of climate, since it is the parameter for which we have the best record and it is most directly relevant to the component of the biosphere that we know best -- humans.

Radiative Forcing (also called "external forcing," "forcing," or "perturbation")

A change imposed on the climate system (as opposed to generated by the internal dynamics of the climate system) that modifies the radiative balance of the climate system. Examples include: changes in the output of the sun or the orbit of the Earth about the sun, increased concentrations of particles in the atmosphere due to volcanoes or human activity, and increased concentrations of greenhouse gases in the atmosphere due to human activity. Radiative forcing is often specified as the net change in energy flux at the troposphere (W/m^2) or the equilibrium change in surface temperature in the absence of feedbacks (°C).

General Circulation Model (GCM)

A computer model of the Earth's climate based on equations that describe, among other things, the conservation of energy, momentum, and mass, and which explicitly calculates the distribution of wind, temperature, precipitation, and other climatic variables. Such models are applied to the atmosphere, to the oceans, or to both coupled together.

Carbon Intensity

The ratio of carbon dioxide emissions to unit primary energy consumption (10^6 tons CO_2 divided by total energy consumption measured in exajoules).

Global Warming Potential (GWP)

A concept utilized by the IPCC to put the relative ability of different greenhouse gas emissions to affect climate on a common basis. The GWP accounts for differences in molecular structure and atmospheric lifetime of the various greenhouse gases, and expresses their radiative forcing relative to that of CO_2.

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* Adapted from *Policy Options for Stabilizing Global Climate*, Draft Report to Congress, U.S. EPA, Office of Policy, Planning, and Evaluation, Washington, D.C., 1989.

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STATEMENT OF THE SEVEN MAJOR INDUSTRIAL DEMOCRACIES

. . . One of our most important responsibilities is to pass on to future generations an environment whose health, beauty, and economic potential are not threatened. Environmental challenges such as climate change, ozone depletion, deforestation, marine pollution, and loss of biological diversity require closer and more effective international cooperation and concrete action. We as industrialized countries have an obligation to be leaders in meeting these challenges. We agree that, in the face of threats of irreversible environmental change, lack of full scientific certainty is no excuse to postpone actions which are justified in their own right . . .

. . . Climate change is of key importance. We are committed to undertake common efforts to limit emissions of greenhouse gases, such as carbon dioxide. We strongly support the work of the Intergovernmental Panel on Climate Change (IPCC) and look forward to the release of its full report in August . . .

. . . We welcome the amendment of the Montreal Protocol to phase out the use of chlorofluorocarbons (CFCs) by the year 2000 and to extend coverage of the Protocol to other ozone depleting substances . . .

. . . To cope with energy-related environmental damage, priority must be given to improvements in energy efficiency and to the development of alternative energy sources . . .

. . . We are determined to take action to increase forests, while protecting existing ones and recognizing the sovereign rights of all countries to make use of their natural resources . . .

. . . Cooperation between developed and developing countries is essential to the resolution of global environmental problems . . .

Excerpted from
THE HOUSTON ECONOMIC DECLARATION

Signed by the Heads of State and Government
of the seven major industrial democracies
and the President of the Commission of the European Communities
July 11, 1990

EXECUTIVE SUMMARY

1. BACKGROUND AND PURPOSE

This report responds to the Fiscal Year 1990 Foreign Assistance Appropriations Act, which requested the Agency for International Development (A.I.D.) to prepare a report that (1) examines the potential contributions of developing countries to future global emissions of greenhouse gases under different economic growth scenarios, (2) estimates the relative contributions of those countries to global greenhouse gas emissions, and (3) identifies specific key countries that stand to contribute significantly to global greenhouse gas emissions, and in which actions to promote energy efficiency, reliance on renewable resources, and conservation of forest resources could significantly reduce emissions of greenhouse gases.

The report presents ongoing programs and new initiatives being considered by A.I.D. to promote sustained economic growth in developing countries while minimizing greenhouse gas emissions. Estimates of present and projected emissions, including emissions from A.I.D.-designated "key countries," are based on the work of the Intergovernmental Panel on Climate Change (IPCC).

Despite the uncertainties regarding the timing, magnitude, and impacts of global climate change, the issue has dramatized the daunting problems faced by developing countries in achieving sustained economic and social development. Responding to the policy imperative of "managing the global commons" while accelerating development in individual countries is one of the significant challenges of our time.

2. CONTRIBUTIONS OF DEVELOPED AND DEVELOPING COUNTRIES TO GREENHOUSE GAS EMISSIONS

The OECD countries, the Soviet Union and Eastern Europe currently produce over 50 percent of the greenhouse gas emissions, or five times as much per capita as the rest of the world. (These estimates are based on the concept of "global warming potential," which is used to compare the potential warming effects of different greenhouse gases.) Carbon dioxide accounts for about half of the "global warming potential" of all greenhouse gases, and the energy sector produces about half of total emissions. Carbon dioxide emissions from fossil fuel combustion and chlorofluorocarbon (CFC) emissions are known fairly accurately, while carbon dioxide emissions from deforestation and total methane emissions from the different sources are not yet well quantified.

The industrialized countries are likely to account for a declining share of future emissions, while the rapidly industrializing developing regions will contribute a substantially greater share over the next

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three to five decades, because they must increase their per capita energy use to further their economic growth.

In developing countries the burning of biomass associated with deforestation contributes substantially to greenhouse gas emissions, but increases in commercial energy use will be the largest future source of such emissions. In principle, forests can be transformed from carbon sources to carbon sinks, if they don't disappear before forest stabilization programs are instituted. The agricultural sector is an important source of methane and nitrous oxide, principally resulting from rice production, domestic animals, fertilizer use and biomass burning, but taken individually, these contributions appear to be small in comparison with natural emissions; collectively, they represent about 60-70% of total CH_4 emissions.

Even though the concentration of greenhouse gases in the atmosphere is likely to grow over the next few decades, the rate of growth will depend on the extent to which successful policies to control emissions can be implemented. Stabilization of greenhouse gas concentrations over the next century can be brought about through rapid implementation of energy efficiency measures, major increases in non-fossil energy supplies, reduced growth in fossil fuel emissions, and significant forest management and conservation efforts. Successful introduction and diffusion of these measures will require significant innovation on all fronts -- technological, policy, financing, and institutional. No single innovative approach or technology can adequately control greenhouse gas emissions, but by implementing a balanced and comprehensive strategy over the next few decades, significant reductions in emissions can accompany accelerated economic growth in the developing nations.

Yet, even with the most aggressive energy efficiency strategies in developing countries, total energy use in these countries will continue to grow for many decades. However, even in the highest growth scenario developed by the IPCC, the *per capita* contributions of developing countries to greenhouse gas emissions in the year 2025 are at most 10-20% of those of the OECD countries.

The rapid deployment of highly efficient energy systems will be central to sustainable development strategies based on technological and industrial modernization for all countries and regions. The use of available technologies and practices, particularly for increasing end-use energy efficiency, can mitigate greenhouse gas emissions.

3. A.I.D.'S ON-GOING PROGRAMS AND PROPOSED INITIATIVES IN ENERGY, FORESTRY, AND AGRICULTURE

A.I.D. is pursuing a strategy on global change that supports robust, sustainable development paths valid in the face of scientific uncertainty. This strategy is consistent with the "no-regrets" policy enunciated recently by Secretary of State James Baker. Thus, investments in energy efficiency,

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sustainable forest resource management, agricultural research and institutional strengthening, and biological diversity are developmentally sound regardless of the pace and nature of climate change.

In Fiscal Year (FY) 1989, the Agency provided $185 million in support of global-warming-related activities, defined as including all forestry, energy efficiency and renewable energy programs. Planned funding levels for fiscal years 1990 and 1991 are $225 million and $248 million, respectively. The present level of assistance supports activities in about 40 A.I.D. missions, as well as in additional countries, through regional and centrally-funded programs.

On-Going Programs

A.I.D. is implementing a multifaceted strategy for improving energy sector performance in developing countries. There is a major focus on policy reform, including pricing, least-cost planning, private sector involvement, improved energy system and environmental management, and clean energy technology commercialization. A balanced program of supply- and demand-side technological innovation stresses energy efficiency, renewables, and clean fossil options. The Agency is also supporting several initiatives in collaboration with the multilateral development banks and other bilateral donor agencies through the Multi-Agency Group on Power Innovation (MAGPI) and other mechanisms. Key countries in which such energy programs are underway include Brazil, India, Indonesia, Pakistan, the Philippines and Costa Rica (included in the key region of Central America). There are also important energy programs in the Dominican Republic, Egypt, Jordan, Thailand, and Morocco. The key countries of Mexico, Poland, and Zaire are candidates for new programs.

A.I.D. support for forestry activities is growing rapidly. In FY 1988, $50.2 million was obligated for 90 active projects. By the following year, A.I.D.'s portfolio included 112 projects, and obligations had increased to $76.8 million, a 53 percent growth rate. A.I.D. has launched several noteworthy initiatives. In collaboration with the U.S. Environmental Protection Agency (EPA), A.I.D. has commissioned the National Academy of Sciences to assess the potential of sustainable agriculture to reduce rates of deforestation, to identify requirements for overcoming the constraints to adoption of sustainable agricultural systems, and to recommend sites for implementation of sustainable agriculture projects.

In May 1988, A.I.D. announced a debt-for-development initiative. Under the program, A.I.D. supports the purchase -- normally through non-governmental organizations (NGOs) -- of discounted debt owed by developing countries to foreign commercial banks. Forestry projects in the Philippines and Madagascar have been supported under this initiative.

A.I.D. is providing financial support in Guatemala for the first project intended to offset the carbon dioxide emissions of a new coal-fired power plant in Connecticut. The project consists of a number of

forestry interventions designed to sequester 15.5 million tons of CO_2 over 40 years, equivalent to the carbon dioxide emitted by the coal plant.

Proposed Initiatives

A Global Energy Efficiency Initiative (GEEI) has been launched by A.I.D. with the active collaboration of an *ad hoc* working group composed of representatives from EPA, DOE, national laboratories, and NGOs. The goal of this effort is to implement an international program of energy efficiency. This is being carried out as a part of A.I.D.'s new set of Environmental Initiatives announced by Administrator Ronald Roskens on June 28, 1990.

A.I.D. is expanding its support for the transfer of existing technologies and practices, as well as for joint venture energy technology development and commercialization. A.I.D., in collaboration with other U.S. government agencies, will contribute to export promotion, technology transfer, and training. New training initiatives will address the needs of A.I.D. and host country governments for authoritative information on global climate change as well as on policy responses and technological options to reduce greenhouse gas emissions while promoting economic growth. The international energy and environment community is discussing mechanisms to foster a market-driven approach to energy technology development and commercialization through support of joint ventures and consortia in developing and developed countries.

A.I.D. is working with the U.S. Electric Power Research Institute (EPRI), and with electric utilities in Western Europe, Japan, Canada, India, Taiwan, Korea, and other developing countries to explore the formation of an international electric utility industry network to sponsor collaborative research and technology development related to climate change.

Key climate-related initiatives in the forestry area will include:

- Collaborative efforts to strengthen international tropical forest research and the institutional mechanisms to carry it out;
- Expanded technical services in forest management, agroforestry, buffer zone development, conservation, and nature tourism;
- Research and analysis looking toward development and implementation of policy packages to identify and address important, root causes of tropical deforestation and degradation, including market failures and policy distortions;
- Strengthening the institutional and human resource capabilities to conduct research and implement appropriate policies and programs.

A.I.D. is planning to implement in FY 1991 a Sustainable Agricultural Systems Collaborative Research Support Program (CRSP) that will integrate agricultural, environmental, and social sciences within A.I.D.'s agricultural portfolio. In the agricultural sector, the establishment of a global network will be explored to monitor stocks of organic carbon in soil at existing long-term research sites in developed and developing countries, and to relate changes in stocks to land-use management practices. Such a network could also monitor greenhouse gas emissions and relate these emissions to land-use patterns. These efforts would be cost-effective since they draw on existing programs.

CHAPTER 1

INTRODUCTION AND OVERVIEW

SUMMARY

Prepared as a response to the Congressional directive, this report analyzes current greenhouse gas emissions data for developed and developing countries (including A.I.D.-designated "key" developing countries) and postulates future levels of emissions under different economic growth scenarios. Key developing countries, identified on the basis of subjective and objective factors, face the triple-bind problem of inadequate capital mobilization for energy development, deteriorating performance of electric utilities, and severe environmental issues. This situation calls for unprecedented collaborative actions and strategies between the industrialized and developing countries to accelerate economic growth while minimizing greenhouse gas emissions.

1.1 GREENHOUSE GASES AND CLIMATE CHANGE

Human activities affect the Earth's climate through the release of "greenhouse gases"* to the atmosphere, and through changes in the physical properties of the surface by deforestation, agriculture, and the expansion of human settlements. The atmospheric buildup of greenhouse gases due to human activities appears to be the dominant anthropogenic force on global climate change. In terms of climate impact, the most important gases released through human activities are carbon dioxide, methane, nitrous oxides, halons, and chlorofluorocarbons or CFCs.

While the emissions of greenhouse gases and their contributions to changes in the thermal properties of the atmosphere are documented by scientific evidence, there is not yet scientific consensus on the likely climate impact of the atmospheric buildup of these gases. Concern for the consequences of human-induced increases in the greenhouse gases has been well summarized in a recent World Bank Discussion Paper:[1]

> The emission of greenhouse gases is expected to induce an increase in the global mean temperature which, in terms of either magnitude or rate of change, would be unprecedented in mankind's entire history on earth. Present day global climate models predict a warming of 1.5°-4.5°C for a CO_2 doubling within the next century. In contrast, the earth's temperature has risen only 0.5-0.7°C in the last century, and probably has not varied more than 1-2°C in the last ten thousand years, or 6-7°C in the last million years.

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* "Greenhouse" gases include water vapor, carbon dioxide, methane, nitrous oxide, and certain manmade chemicals that absorb and reradiate some of the heat radiated from the earth's surface. In a rough sense, these gases trap some of the heat that would normally escape as radiant energy into space; hence, the analogy to a greenhouse. This interception of radiant energy contributes to overall heating of the atmosphere.

> The development of the human social and cultural infrastructure over the last 7,000 years has taken place entirely within an average global climate neither 1° warmer nor colder than the climate of today.

While there are apparent differences of opinion about the nature, extent, and speed of the changes associated with this warming, the issue of global climate change has highlighted and dramatized the serious problems that developing countries face in achieving sustained environmentally sound economic and social development. Responding to these growing global concerns without hampering the development process in the world's lower- and middle-income countries is likely to be one of the significant challenges of our time.

Despite the uncertainties about the timing and magnitude of any change, the potential for global warming is increasingly accepted by the international community. The U.S. has been a leader in coordinating an international response to the threat of climate change through the Intergovernmental Panel on Climate Change (IPCC).

1.2 PURPOSE AND FOCUS OF THE REPORT

This report has been prepared as a response to the Congressional directive and guidance contained in Section 534(c)(1) of the Fiscal Year 1990 Foreign Assistance Appropriations Act (Public Law 101-167), which states that:

> The Agency for International Development, in consultation with the Environmental Protection Agency (EPA), the Department of State, and other appropriate agencies, shall submit to Congress a report which (1) examines the potential contributions of developing countries to future global emissions of greenhouse gases under different economic growth scenarios, (2) estimates the relative contributions of those countries to global greenhouse gas emissions, and (3) identifies specific key countries which stand to contribute significantly to global greenhouse gas emissions, and in which actions to promote energy efficiency, reliance on renewable energy resources, and conservation of forest resources could significantly reduce emissions of greenhouse gases. This report should utilize existing data, including the models and methodologies already developed by the EPA for their report to Congress on "Policy Options for Stabilizing Global Climate."

This report to Congress does not attempt to review the science of climate change or the controversies surrounding the subject. Many excellent discussions and summaries of this topic addressed to both the scientific and policy communities have appeared over the past several years. Rather, this report provides an overview of the physical sources of the various greenhouse gases, their geographic distribution, and estimates of future emissions over the coming century. These estimates are based on the work of specialized committees and participating national study teams of the Intergovernmental Panel

on Climate Change* (IPCC), which will issue its formal report later this year. The present and projected emissions from A.I.D.-designated "key countries" are also presented. While this report summarizes some of the technical- and policy-related aspects of controlling greenhouse gas emissions, the focus of the report is on the ongoing programs and actions proposed by the Agency for International Development to assist developing countries in achieving sustained economic growth while minimizing both local and global environmental consequences with specific reference to controlling greenhouse gas emissions.

1.3 CHALLENGES TO THE INDUSTRIALIZED AND DEVELOPING COUNTRIES FROM CLIMATE CHANGE

Eventual stabilization of the atmospheric concentrations of greenhouse gases and the attendant global climate change will require sustained implementation of a long-term strategy. Addressing the climate change problem requires an appreciation of the problems that developing countries face in managing energy/power demand, forest resources, and agriculture. Energy activities are the most significant, however, contributing 60% of greenhouse gas emissions in terms of the potential for impacting climate.

The U.S. and other OECD countries are likely to account for a declining share of future greenhouse gas emissions, while the rapidly industrializing developing regions will contribute a substantially greater share over the coming three to five decades. This is principally because in virtually all developing countries per capita commercial energy use is a small fraction of the per capita energy use of even the poorest European countries. Even with the most aggressive energy efficiency strategies in developing countries, total energy supply for fuels and electricity will continue to grow for many decades. Clearly they will need to be a key part of the search for solutions, because they represent the largest share of expected increases over the next century.

In the electric power sector, developing countries face the triple-bind problem of inadequate capital mobilization for electric power development, deteriorating financial, institutional, and technical performance of their electric utilities, and increasingly severe environmental constraints. Only about $10 billion of the projected $100 billion per year required for developing country power systems development will be available from all external sources, including both official bilateral and multilateral development assistance agencies as well as private creditors.

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* The Intergovernmental Panel on Climate Change (IPCC) was established under the auspices of the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). The IPCC has established three working groups. Working Group #1 is assessing the state of scientific knowledge on climate change and is chaired by the United Kingdom. Working Group #2 is assessing the potential social and economic impacts of climate change and is chaired by the Soviet Union. Working Group #3 is examining potential response strategies to limit emissions and to adapt to climate change; it is chaired by the United States.

An effective response to the challenge of this triple bind must include innovative approaches on all fronts. Neither policy reforms nor management improvements nor technological innovation alone can solve the problem of how to increase the per capita delivery of electrical services in the developing countries under severe capital and environmental constraints. A multifaceted approach will be necessary, posing a difficult challenge for the international community.[2] While the environmental problems of the developing countries were perceived as local in nature, they could be ignored by the larger international community. The recognition of the global environmental dimensions of development has accelerated the search for new paths to economic development consistent with both local and global environmental harmony. Many of the actions to address these problems are by and large required independent of the magnitude and timing of possible global climate change. This is, in effect, the "no regrets" policy that has a broad international appeal.

RATIONALE FOR THE "NO REGRETS" POLICY UNDERLYING U.S. RESPONSES TO THE CHALLENGE OF GLOBAL CLIMATE CHANGE

. . . We can probably not afford to wait until all of the uncertainties have been resolved before we do act. Time will not make the problem go away . . .

. . . While scientists refine the state of our knowledge, we should focus immediately on prudent steps that are already justified on grounds other than climate change. These include reducing CFC emissions, greater energy efficiency and reforestation . . .

. . . Whatever global solutions to global climate change are considered, they should be as specific and cost-effective as they can possibly be . . .

. . . Solutions will be most effective if they transcend the great fault line of our times, the need to reconcile the transcendent requirements for both economic development and a safe environment . . .

The Honorable James A. Baker III, Secretary of State
before the Response Strategies Working Group,
Intergovernmental Panel on Climate Change
Department of State
January 30, 1989

Many developing countries are also facing major challenges to the sustainability of both forest resources and agriculture. The need to maintain and expand tropical forest resources and habitat and to halt deforestation, to minimize ecological disruption and desertification, to conserve biological diversity, and to expand the basis for sustainable agriculture underlies many of A.I.D.'s programs. Success in these areas also restrains growth in greenhouse gas emissions from deforestation and from reduction of land clearing for non-sustainable agriculture.

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Effective strategies and actions to accelerate economic growth in the developing world, while minimizing the environmental burdens of this growth, require three essential elements:

1. Wealthier industrialized nations must take a global lead through exemplary actions, including:

   - establishing innovative institutional mechanisms to support research, development, technology commercialization, and policy changes worldwide;
   - establishing financial and institutional resources to support these mechanisms;
   - implementing energy efficiency measures, both in supply and demand (such measures, to be credible, must be taken domestically as well as internationally); and
   - assisting developing nations in implementing forest conservation measures and developing alternative and environmentally sound natural resource management practices and policies that provide economic returns to local populations.

2. Policies and actions expected of all nations in addressing greenhouse gas emissions must be equitable in terms of the roles and contributions of the wealthier and the developing countries.

3. Solutions that already exist as prototypes must be developed and replicated on a large scale.

In this report key attention is given to energy strategies to reduce greenhouse gas emissions. This focus is taken because (1) fossil fuel combustion is the major contributor to these emissions and (2) the actions which should be taken in the energy sector are the best understood, and could, in principle, be implemented on a reasonable time scale. Energy strategies are more readily quantifiable as to impact and cost than related strategies in the forestry and agriculture sectors.

1.4 A.I.D. KEY COUNTRIES

A.I.D. has used two sets of criteria in its selection of the key countries: (1) data that describe the present and potential contribution of each country to greenhouse gas emissions; and (2) assessments that reflect the political and institutional aspects of U.S. assistance. Based on these criteria, the following "key countries" and "key region" were selected:

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Key Countries	Key Countries	Key Region
Brazil	Pakistan	Central America*
India	Philippines	
Indonesia	Poland	
Mexico	Zaire	

China was not considered for key country status because of current political problems. However, A.I.D. recognizes that China should play an important role in any overall global warming policy initiative. A.I.D. will work with EPA and DOE to develop possible collaboration with China in the event that circumstances change and that country is reconsidered for key country status.

India is expected to increase its use of indigenous coal reserves as part of the national plan to expand installed power generation capacity by 100,000 megawatts (MW) over the next ten years. A.I.D. has extensive experience in India and is supporting major Indo/U.S. projects involving forestry, energy efficiency, technology innovation, and renewable energy. These projects include a multi-agency-sponsored power assessment and energy efficiency project, promotion of clean coal technologies, and major technology development and commercialization efforts. These programs allow A.I.D. to expand activities in India under A.I.D.'s Global Warming Initiative.

The rapid deforestation in the Amazon region and its associated significant CO_2 emissions has led to designation of Brazil as a key country.

Central America was chosen because of the region's growing energy use, increasing rates of deforestation, and the opportunity for A.I.D. to develop model programs in forestry, and in energy efficiency and planning. The knowledge and expertise A.I.D. has gained in the region has allowed the Agency to carry out long-term projects and gain specific awareness about the special needs of the region. A.I.D.'s regional Mission in Central America, the Regional Office for Central America and Panama (ROCAP), provides an organizational mechanism for developing a regional response.

Designation of other key countries reflected a combination of current and expected future contributions to global warming, and a reliance on the subjective factors outlined above. For example, Zaire was chosen over the Ivory Coast and Nigeria, which had higher rates of deforestation, because there is very little forest resource left in the Ivory Coast, while Zaire's forest resources are still quite extensive

* Central America includes Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. The region will be treated as a key country in this report.

and merit additional efforts to preserve them.* Poland's carbon intensity is very high, indicating that the country could benefit from implementation of energy efficiency programs.

NOTES AND REFERENCES

1. E. Arrhenius and T. W. Waltz. 1990. *The Greenhouse Effect: Implications for Economic Development.* World Bank Discussion Paper 78. World Bank, Washington DC.

2. Jhirad, D. 1990. Power Sector Innovation in Developing Countries: Implementing Multi-Faceted Solutions. *Annual Review of Energy*, Volume 15, pp. 365-398. Annual Review, Inc. Palo Alto, California.

* A.I.D. is considering broadening the Zaire key country designation to include the Central African region which also includes the Central African Republic, Congo, Cameroon, and Gabon.

CHAPTER 2

CURRENT CONTRIBUTIONS OF DEVELOPED AND DEVELOPING COUNTRIES TO GREENHOUSE GAS EMISSIONS

SUMMARY

Carbon dioxide emissions are primarily due to fossil fuel combustion and deforestation, methane and nitrous oxides are principally from agricultural practices, and CFCs are released exclusively as a result of industrial processes. Together, the OECD countries, Eastern Europe, and the Soviet Union are responsible for 54% of all greenhouse gas emissions in terms of their impact on the radiative properties of the atmosphere. Worldwide, fossil fuel use accounts for half of emissions impacts. Developing countries contribute a sizable fraction of the global emissions that include carbon dioxide releases from deforestation and methane emissions from rice cultivation. The relative contributions of current greenhouse gas emissions to global climate change are discussed below by gas, sector, and region.

2.1 INTRODUCTION

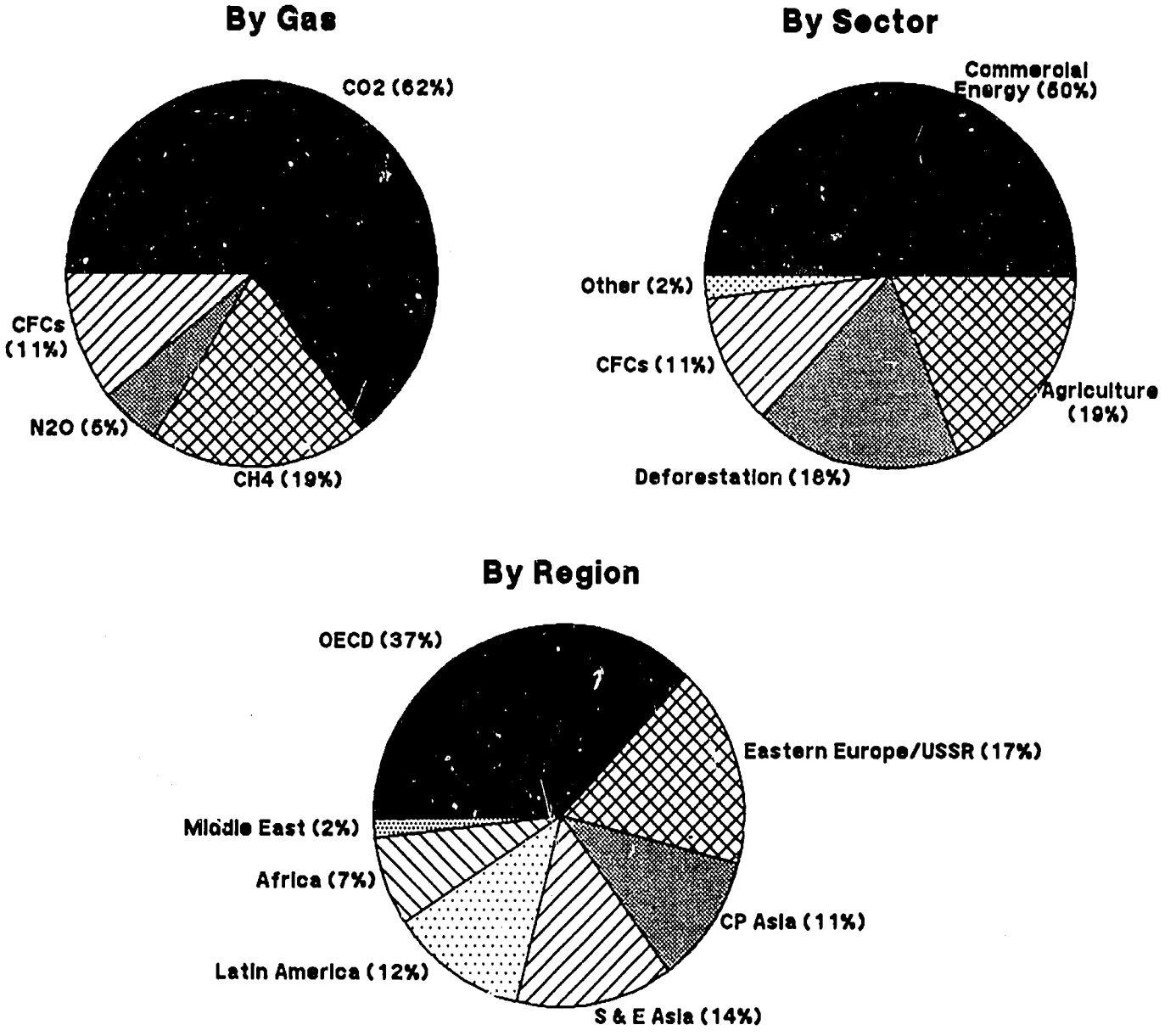
Greenhouse gases that affect the Earth's climate are released to the atmosphere through human activities. These activities, referred to as anthropogenic sources, include fossil fuel combustion, deforestation, land-use change, agriculture, and various industrial processes. The developed countries are presently the source of most greenhouse gas emissions, particularly carbon dioxide. In some cases, including carbon dioxide releases from deforestation and methane emissions from rice cultivation, developing countries contribute a sizable fraction of the global total. The relative contributions of present greenhouse gas emissions to climate change, by gas, sector, and region, are illustrated in Figure 2-1.

This chapter summarizes our understanding of the present levels of greenhouse gas emissions from developed and developing countries.* The following gases are included: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and halons. Tropospheric ozone, a greenhouse gas that is not emitted directly by human activity but whose concentration is strongly governed by trace gas emissions resulting from industrial activity and transportation, will not be discussed here because its anthropogenic sources and its contribution to greenhouse warming are not well quantified. Following an overview of the relative effect of different gases on climate warming and the regional distribution of emissions, the human activities that release trace gases are discussed.

* "Present" in this chapter is defined as the year 1985, except where noted.

FIGURE 2-1

RELATIVE CONTRIBUTION OF 1985 EMISSIONS TO RADIATIVE FORCING



Sources: Marland et al. (1989);[1] Houghton et al. (1987);[2] Cicerone and Oremland (1989);[3] IRRI (1986);[4] Lerner et al. (1987);[5] Fung, pers. communication; Crutzen et al. (1979);[6] Bingemer and Crutzen (1987);[7] United Nations (1987);[8] Bolle et al. (1986);[9] FAO (1987);[10] U.S. EPA (1988);[11] Shine et al. (1990).[12]

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2.2 THE CONCEPT OF "GLOBAL WARMING POTENTIAL"

The relative ability of different greenhouse gas emissions to affect climate can be put on a common basis. One approach, used by the IPCC, is the concept of the "Global Warming Potential" (GWP). The GWP* accounts for differences in molecular structure and atmospheric lifetime of the various greenhouse gases, and expresses their "radiative forcing"** relative to that of CO_2.

The GWP concept is fairly new, and there is still disagreement in the policy community over the most appropriate methodology for calculating GWPs. This report uses the GWPs developed by consensus within the Intergovernmental Panel on Climate Change (IPCC)[12] as shown in Table 2-1. For example, 1 kilogram of methane emitted to the atmosphere is estimated to have 21 times the impact on radiative forcing as does 1 kilogram of carbon dioxide. **These GWPs will be used throughout the report to convert greenhouse gas emissions to a CO_2-equivalent basis.** (The use of the GWPs rather than the "greenhouse index" recently introduced by the World Resources Institute is discussed in Note 13.[13]) Total and *per capita* emissions of the major greenhouse gases by region and key country, on a CO_2-equivalent basis, are presented in Table 2-2.

TABLE 2-1
GLOBAL WARMING POTENTIALS

Trace Gas	GWP[a]
CO_2	1
CH_4	21
N_2O	290
CFC-11	3,500
CFC-12	7,300

[a] Global Warming Potentials following the instantaneous injection of 1 kg of each trace gas, relative to CO_2, for a 100-year time horizon.

Source: Shine et al. (1990).[12]

* Technically, the GWP is defined as the time-integrated commitment to climate forcing from the instantaneous release of 1 kilogram of a greenhouse gas expressed relative to that from 1 kilogram of carbon dioxide.

** "Radiative forcing" is defined as a change imposed on the climate system that modifies the radiative balance of the climate system, i.e., that modifies the balance between incoming and outgoing radiation.

TABLE 2-2

ANTHROPOGENIC GREENHOUSE GAS EMISSIONS BY REGION/KEY COUNTRY
1985
(MMT CO_2 Equivalent)

REGIONS	CO_2[a]	CH_4[b]	N_2O[c]	CFCs[d]	Total Emissions	Percent	Emissions Per Capita
OECD	9,487	1,635	734	3,135	14,853	37.1	18.3
Eastern Europe/USSR	5,046	911	236	710	6,878	17.2	16.5
Poland	432	123	18	64	636	1.6	17.1
Centrally Planned Asia	2,775	1,284	224	90	4,369	10.9	3.8
China	2,168	1,028	160	55	3,410	8.5	3.3
Middle East	524	69	18	40	650	1.6	5.9
Africa	2,005	635	180	200	3,020	7.5	5.3
Zaire	132	28	15	11	186	0.5	6.1
Latin America	3,280	985	331	140	4,730	11.8	11.8
Brazil	1,394	482	155	46	2,077	5.2	15.7
Mexico	381	88	29	29	526	1.3	6.4
Rest of Central America	206	49	25	9	288	0.7	11.4
South and East Asia	2,832	2,187	206	270	5,572	13.9	4.0
India	495	1,011	56	39	1,602	4.0	2.1
Indonesia	789	294	93	58	1,234	3.1	7.5
Pakistan	50	81	7	34	171	0.4	1.8
Philippines	240	101	27	19	387	1.0	7.1
Thailand	394	227	44	18	683	1.7	13.2
WORLD	25,949	7,707	2,020	4,580	40,270	100.0	8.3

NOTE: Because of rounding, sums of regional emissions may not exactly equal totals shown.

[a] Includes emissions from fossil fuel use, tropical and temperate deforestation and reforestation, and cement production.

[b] Includes emissions from rice paddies, livestock, fossil fuel production, biomass burning, and landfills.

[c] Includes emissions from fertilizer use, land clearing, biomass burning, and fossil fuel combustion.

[d] Includes CFC-11, CFC-12, CFC-113, HCFC-22, Halon 1301, carbon tetrachloride, and methyl chloroform.

Sources: Marland et al. (1989);[1] Houghton et al. (1987);[2] Cicerone and Oremland (1989);[3] IRRI (1986);[4] Lerner et al. (1988);[5] Fung and Matthews pers. communication; Crutzen et al. (1979);[6] Bingemer and Crutzen (1987);[7] United Nations (1987);[8] Bolle et al. (1986);[9] FAO (1987);[10] U.S. EPA (1988);[11] Shine et al. (1990);[12] Zachariah and Vu (1988);[14] FAO (1986).[15]

Greenhouse Gas Emissions Data and Uncertainties

A.I.D. has not conducted an independent review of the data sources and data quality. The emissions data used in the report are based directly on the data currently used by the IPCC and the U.S. Environmental Protection Agency (EPA) in their own extensive investigations of greenhouse gas emissions and impacts and are extensively referenced in the text.

The uncertainties in the emissions data presented in this report do not affect the response strategy proposed by the Agency. For example, even if the lower bound of the large uncertainty range for carbon dioxide emissions from deforestation were correct, the associated rate of deforestation warrants the forest management initiatives presented in Chapter 7.

Greenhouse gas emissions data are presented in this report at the global, regional, and national levels and are presented in terms of their carbon dioxide equivalents rather than in primary physical units. The primary physical data for emissions of methane, nitrous oxide, and CFCs have each been converted to a CO_2-equivalent basis using the concept of the Global Warming Potential (GWP) as discussed in the text (page 2-3).

The use of the GWP method to convert the impact of the various greenhouse gases to a common measure, expressed in terms of the equivalent emissions of CO_2, has been adopted by the IPCC. However, there are discussions underway in the scientific community regarding the most appropriate methodology for comparing the impacts of the various greenhouse gases. For the purposes of this Report, the use of the GWP provides the best way to compare the various sources and impacts of greenhouse gas emissions.

There are uncertainties in the available greenhouse gas emissions primary data. These uncertainties are discussed in the report and illustrated in the figures presented in Chapter 2. In the data tables the emissions data are presented as single values (usually the mid-point of the uncertainty range), with the uncertainties summarized either in the table, a corresponding figure, or the text.

The sources of the uncertainties include limitations in physical monitoring programs and measurement capabilities, differing interpretations of satellite data on changes in land cover, and different methodologies used to estimate emissions. Also, the degree and accuracy of greenhouse gas monitoring activities vary substantially from one county to another. In many cases the country-level estimates developed by the IPCC and EPA are based on limited information.

The degree of uncertainty varies by gas, by source (e.g., energy, deforestation, agriculture), and by geographic area. Uncertainties in carbon dioxide emissions from fossil fuel combustion are small because fuel use is well known worldwide, and the carbon dioxide emissions from combustion of coal, oil, and natural gas are very well understood. By contrast, the uncertainty range for the data used for carbon dioxide emissions from deforestation is very large, with a range of 1,450-9,500 MMT CO_2-equivalent per year. The upper end of the range is equivalent to about one-half of the CO_2 emissions from fossil fuels. The lower end of the range is equivalent to about 8%. Recent satellite measurements for Brazil support both lower rates of deforestation and a narrower uncertainty range than indicated in the IPCC data used in this Report. In general, the most reliable greenhouse gas emissions data presented in this Report are at the global level of aggregation.

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2.3 EMISSIONS OF THE MAJOR GREENHOUSE GASES

2.3.1 Carbon Dioxide

Carbon dioxide is the most abundant and the single most important greenhouse gas (other than water vapor) in the atmosphere. Global anthropogenic emissions of CO_2 in 1985, resulting from fossil fuel combustion, deforestation, and cement production, totaled 21,000-29,000 million metric tons (MMT).[1,2,16,12] The uncertainty in the estimate of total CO_2 emissions is primarily due to large uncertainties in the emissions due to deforestation. Of the total emissions, fossil fuel combustion was responsible for 65-90%, cement production was responsible for 1.5-2%, and deforestation for 7-33% (Figure 2-2).*

Commercial fossil fuel consumption accounts for 65-90% of the total CO_2 emissions from anthropogenic sources. The OECD accounts for almost one-half, and the A.I.D.-designated key countries account for nearly 20% of global CO_2 emissions from commercial energy use (see Table 2-3).

Deforestation from clearing of lands for agriculture, fuelwood, and other purposes is responsible for approximately 7-33% of the anthropogenic CO_2 emissions. About 95% of the CO_2 emissions from this source result from deforestation in the tropics. Six countries were responsible for over half of the tropical release in 1980: Brazil, Indonesia, Colombia, the Ivory Coast, Thailand, and Laos.[2] Estimates of CO_2 emissions from deforestation range from about 8% to 50% of CO_2 emissions from fossil fuel combustion. This wide range is due to uncertainties in the annual regional rates of deforestation, the amount of carbon stored in different types of biomass, and the fate of the biomass cleared. Additional satellite mapping and ground measurements will be required to decrease this uncertainty. Forests play a key role as a major reservoir of carbon. While forests can act as a sink for carbon, increased cutting releases carbon which contributes to greenhouse gas emissions. This is precisely why Brazil with its large forest base is listed

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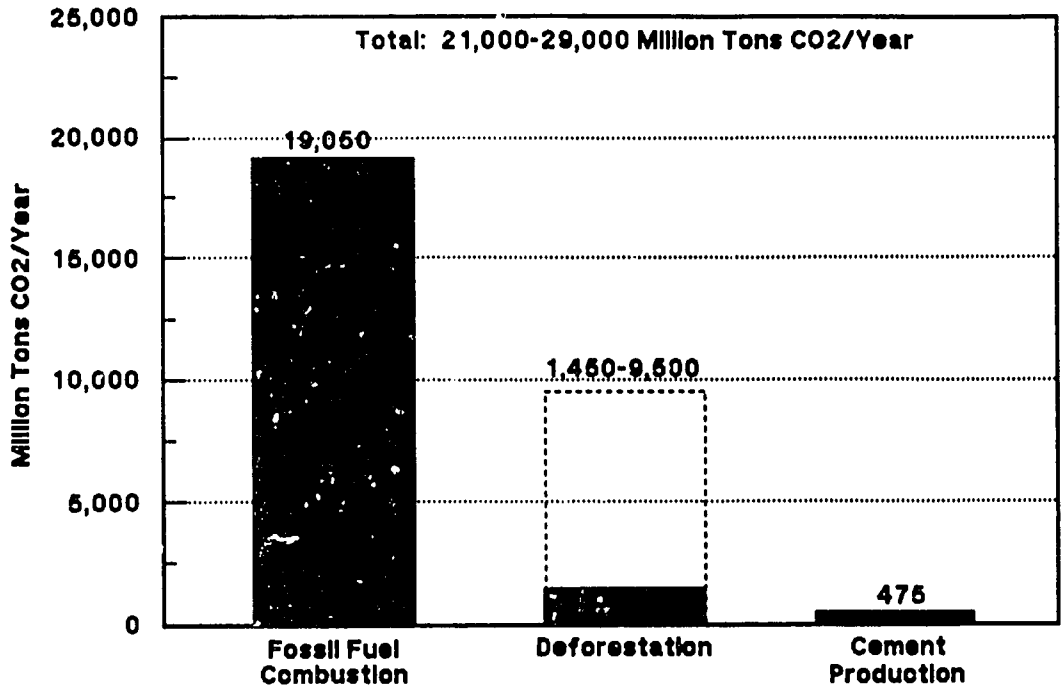
* The estimate of emissions resulting from deforestation is based on rates of land clearing for 1980. Two recent studies conducted by FAO and WRI provide more conclusive data regarding the rates of tropical deforestation. Preliminary results of the FAO "Forest Resources Assessment 1990" project show that estimated 1981-1990 deforestation rates are 17.0 million ha/yr (42 million acres/yr). This estimate, which is grounded on two base years (1980 and 1990), is approximately 50% higher than the original FAO estimate of 11.3 million ha/yr (28 million acres/yr), which is predicated on the single base year of 1980. The recently published WRI *World Resources 1990-91* report gives a somewhat higher rate of tropical deforestation of 20.4 million ha/yr (50 million acres/yr), which is based on recent data obtained from nine selected countries (Brazil, Cameroon, Costa Rica, India, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam). These studies indicate that rates of tropical clearing have increased by as much as 50-90% over the last decade, and therefore that current emissions of CO_2 from deforestation are much higher than was estimated in 1980. WRI quotes a range of annual deforestation rates in Brazil's Amazon of 1.7-8.0 million hectares/yr, but uses 8 million hectares/yr as the most recent estimate. Recent Brazilian data suggest a linear rate of deforestation of 25,000 km^2/year (2.5 million ha/year) ±20%.

FIGURE 2-2

CURRENT CARBON DIOXIDE EMISSIONS



NOTE: The deforestation bar outlined with a dashed line illustrates the uncertainty in the estimate for emissions from this source (see footnote on page 2-6).

Sources: Marland et al. (1989);[1] Houghton et al. (1987);[2] Detwiler and Hall (1988).[16]

TABLE 2-3

COMMERCIAL ENERGY CONSUMPTION, CO_2 EMISSIONS, AND CARBON INTENSITY 1985

REGIONS	Primary Energy Consumption (EJ)[a] Oil	Gas	Coal	Other[b]	Fossil Fuel CO_2 Emissions (MMT CO_2)	Carbon Intensity (MMT CO_2/EJ)	Fossil Fuel CC_2 Emissions Per Capita (Tons CO_2/cap)
OECD	68.50	29.08	34.17	27.45	9,180	57.7	11.3
Eastern Europe/USSR	23.11	21.68	25.70	5.04	4,860	64.3	11.7
Poland	0.90	0.40	4.00	0.00	440	83.0	1.2
Centrally Planned Asia	4.56	0.50	18.01	8.19	1,990	63.7	1.9
China	3.97	0.50	16.89	7.68	1,940	66.8	1.9
Middle East	5.28	2.22	0.10	0.35	490	61.6	4.4
Africa	3.69	1.15	3.33	5.31	610	45.3	1.6
Zaire	0.03	-	0.01	0.39	3	7.0	0.1
Latin America	8.80	2.63	0.77	6.94	810	42.3	2.0
Brazil	1.67	0.05	0.37	3.86	150	25.2	1.1
Mexico	2.79	0.90	0.14	0.65	250	55.8	3.0
Rest of Central America	0.18	-	-	0.40	10	17.2	0.4
South and East Asia	7.56	1.26	4.37	8.45	960	45.3	0.7
India	1.62	0.14	2.62	3.74	360	44.3	0.5
Indonesia	0.96	0.21	0.04	0.61	80	44.0	0.5
Pakistan	0.32	0.32	0.05	0.54	40	32.5	0.4
Philippines	0.37	-	0.05	0.52	30	31.9	0.5
Thailand	0.45	0.10	0.06	0.02	40	63.5	0.8
WORLD	121.49	58.50	86.44	61.72	18,900	57.6	3.9

[a] 1 EJ = 1 Exajoule = 10^{18} joules = 0.95×10^{15} Btus.

[b] Other includes nuclear, hydro, geothermal, commercial and non-commercial biomass, and solar.

Sources: Marland et al. (1989);[1] United Nations (1987);[8] Meyers and Leach (1989);[17] Zachariah and Vu, (1988).[14]

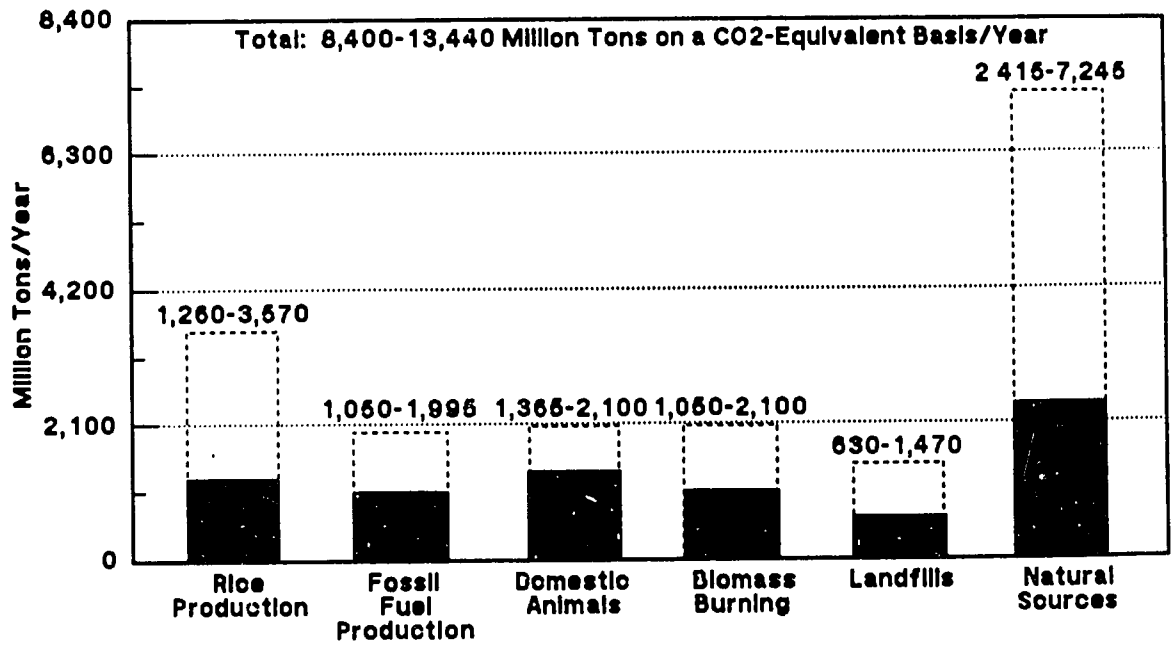
as an A.I.D.- designated key country and why the continued protection of Zaire's forest area is so important.

2.3.2 Methane

Current emissions of methane are 8,400-13,440 MMT/yr on a CO_2-equivalent basis; approximately 60-70% is anthropogenic.[3,12] Natural sources include wetlands, termites, oceans, and freshwaters; anthropogenic sources include paddy rice cultivation, enteric fermentation in domestic animals, coal mining, natural gas leakage, biomass burning, landfilling of organic wastes, and a small amount from incomplete combustion of fossil fuels (Figure 2-3). Estimates of emissions from each source are highly uncertain due to lack of data (e.g., measurements of CH_4 emissions from Asian rice paddies, data on the amount of leakage from natural gas distribution systems).

FIGURE 2-3

CURRENT METHANE EMISSIONS



NOTE: The bars outlined with a dashed line illustrate the uncertainty in estimates of emissions from these sources.

Source: Cicerone and Oremland (1989);[3] Shine et al. (1990).[12]

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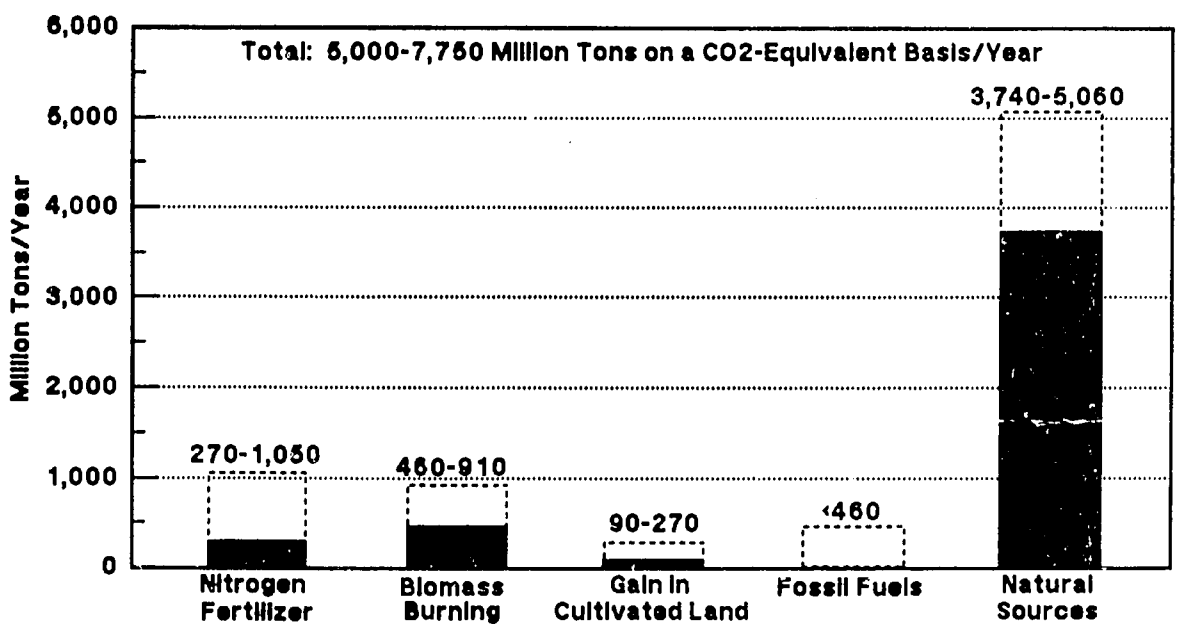
Anaerobic decomposition of organic material in flooded rice fields and enteric fermentation in domestic animals are responsible for 20-50% and 20-35%, respectively, of the total annual anthropogenic CH_4 emissions. Over 90% of the global rice acreage and production occurs in Asia, primarily in the developing countries of this region. In 1984, China, India, Indonesia, Bangladesh, and Thailand together accounted for about 75% of the harvested area and production.[4] Domestic animals that produce the bulk of the CH_4 are (in decreasing order, based on amount of CH_4 produced) non-dairy cattle, dairy cows, buffalo, goats, sheep, camels, pigs, and horses. Currently, approximately 57% of CH_4 from domestic animals comes from non-dairy cattle and 19% from dairy cows. Domestic animals in six countries -- India, the USSR, Brazil, the U.S., China, and Argentina -- produce over 50% of the global annual CH_4 emissions from this source.[5]

2.3.3 Nitrous Oxide

Nitrous oxide emissions levels are uncertain. Current global emissions are estimated at 5,000-7,750 MMT/yr on a CO_2-equivalent basis.[9,12,18] Natural sources, which release about 60% of the emissions, include soils and the oceans. Anthropogenic emissions result from land-use modification (biomass burning and gain in cultivated land), use of nitrogen fertilizers, and fossil fuel use (Figure 2-4). Aquifers and surface waters, contaminated from fertilizers and animal and human wastes, may also release significant amounts of N_2O.[19]

FIGURE 2-4

CURRENT NITROUS OXIDE EMISSIONS



NOTE: The bars outlined with a dashed line illustrate the uncertainty in estimates of emissions from these sources.

Source: Bolle et al. (1986);[9] U.S. EPA (1990);[18] Shine et al. (1990).[12]

Use of nitrogen fertilizers, the most abundant fertilizer nutrient consumed worldwide, contributes 10-30% of the total anthropogenic N_2O emissions. Asia, Western Europe, Eastern Europe, and North America together consumed about 85% of the world's nitrogen fertilizers in 1985/1986. The twelve largest consumers (in decreasing order) are China, the USSR, the U.S., India, France, the United Kingdom, West Germany, Indonesia, Poland, Mexico, Canada, and Italy. Together, these countries account for almost 75% of the annual nitrogen fertilizer consumption.[10]

2.3.4 CFCs and Halons

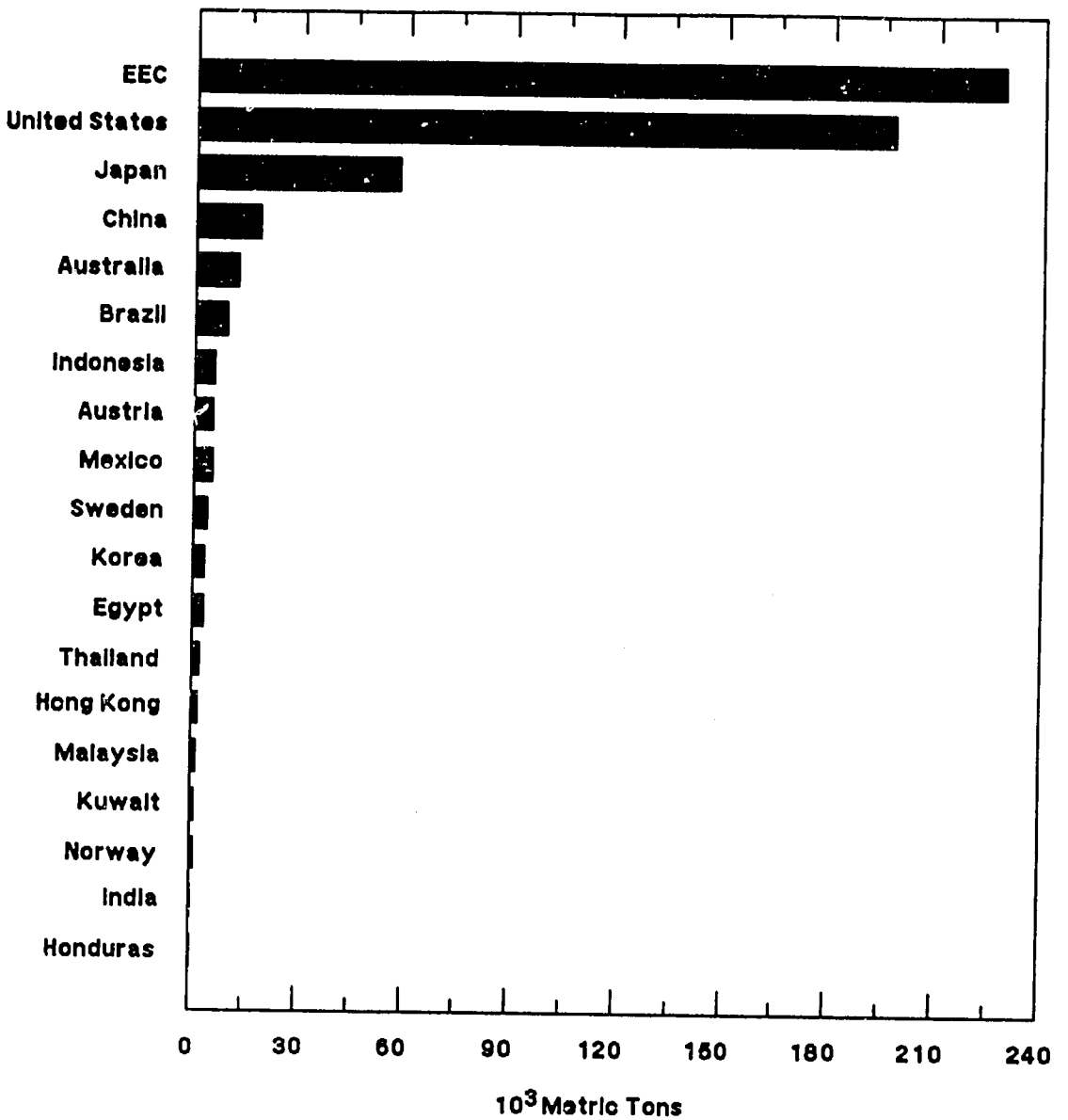
CFCs and halons are man-made chemicals that are produced and used almost entirely by the OECD countries (Figure 2-5). CFCs are used to produce plastic foam, as aerosol propellants and refrigerants, in medical sterilization, and as solvents in the manufacture of electronic components. Halons are used principally in fire extinguishers. CFC demand in the developing world is expected to grow in the future as demand for refrigerators and air-conditioners grows.

Because of concern about the effect of these chemicals on stratospheric ozone, an international agreement to reduce their emissions ("The Montreal Protocol on Substances the Deplete the Ozone Layer," or the Montreal Protocol) was signed in 1987. Under this agreement, developing countries with low levels of per capita use are permitted to delay their compliance for up to ten years. The Protocol was recently strengthened in June 1990, when an international agreement was reached to completely phase out production of the major CFCs and halons by 2000, and production of carbon tetrachloride and methyl chloroform by 2000 and 2005, respectively. Under this new agreement, developing countries will be allowed a 10-year grace period for compliance, and an international fund will be set up to assist them in their transition to CFC-free technologies.

FIGURE 2-5

CFC-11 AND CFC-12 PRODUCTION/USE FOR VARIOUS COUNTRIES IN 1985

(10^3 Metric Tons)



Source: U S. EPA (1988).[11]

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13. The regional emissions presented in this report are different from those in *World Resources 1990-91*, a report recently issued by the World Resources Institute (Washington, DC) because of differences in the methodologies used to convert emissions to a common basis. WRI, to calculate CO_2-equivalent emissions ("the greenhouse index"), used the airborne fraction of total emissions and included only CO_2, CH_4, CFC-11, and CFC-12. CO_2-equivalent emissions presented in this report are based on the anthropogenic portion of total emissions and include CO_2, CH_4, N_2O, CFC-11, CFC-12, CFC-113, HCFC-22, methyl chloroform, and carbon tetrachloride. The relative radiative forcing of the different gases may also have varied between WRI's report and this one; however, not enough information was given in WRI's report to determine this.

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CHAPTER 3

POTENTIAL CONTRIBUTIONS OF DEVELOPING COUNTRIES TO GREENHOUSE GAS EMISSIONS ASSUMING NO POLICY ACTIONS

SUMMARY

The basis for examining the potential contributions of the developing countries to greenhouse gas emissions are the emissions scenarios used by the IPCC. Designed to meet specific targets (doubling of equivalent CO_2 concentrations) by certain future dates, variants of each scenario to reflect higher and lower rates of economic growth are presented. A "business as usual" scenario, in which no major greenhouse gas emission control policies are implemented, projects the share of greenhouse gas emissions attributable to the developing countries from energy, forestry, agriculture, and industrial activities at over 50% of global emissions by 2025. In most of the A.I.D.-designated key developing countries, assuming no policy response to climate change, greenhouse gas emissions rapidly increase by 2025 with major contributions from energy activities, deforestation, agricultural activities, and CFC usage.

3.1 INTRODUCTION

Future greenhouse gas emissions from Eastern Europe, the USSR, and the developing countries will depend on future population growth, economic growth, the amount and types of energy consumed, and the rates and scale of adoption of new policies and technologies. These in turn will be affected by the extent of international financial and technological assistance. This study uses the greenhouse gas emission scenarios developed by the IPCC.* These scenarios were developed to evaluate the consequences of a wide range of future greenhouse gas emission projections. The scenarios were developed from two different sources:

- At an IPCC meeting held in Paris in April 1989, representatives of several countries agreed to prepare a study of future energy use and greenhouse gas emissions for their own countries, including an examination of potential policy options to reduce emissions. The IPCC refers to this scenario as the "EIS/AFOS Reference case".[1] According to the IPCC, these studies have not been officially endorsed by the participating countries and, as a result, should be viewed as preliminary assessments by country experts representing their "best guess" on future energy and emission trends for their respective countries. Some of the individual country assumptions in this reference case are discussed on pp. 3-7 through 3-14.

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* Scenarios developed by the Energy and Industry Subgroup (EIS) and the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) of the Response Strategies Working Group (RSWG) of the IPCC.

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- The Response Strategies Working Group (RSWG) of the IPCC formed an expert group, consisting of representatives of the United States and the Netherlands, to develop scenarios of future emissions of greenhouse gases. These initial reference scenarios provided guidance for the various working groups of the IPCC; they will be referred to as the "Task A" scenarios.[2]

The Task A scenarios describe a series of alternative greenhouse gas emission trends that lead to different rates of atmospheric buildup of greenhouse gases and hence, differences in the rate and magnitude of climate change. The scenarios specify specific targets of atmospheric concentrations by certain future dates. They are:

- *2030 Emissions Scenario*: equivalent CO_2 concentrations reach a value double that of pre-industrial atmospheric concentrations of CO_2 by 2030.
- *2060 Emissions Scenario*: equivalent CO_2 concentrations reach a value double that of pre-industrial atmospheric concentrations of CO_2 by 2060.
- *Control Policies Scenario*: equivalent CO_2 concentrations reach a value double that of pre-industrial atmospheric concentrations of CO_2 by 2090 and stabilize thereafter.
- *Accelerated Policies Scenario*: equivalent CO_2 concentrations stabilize at a level less than a doubling of pre-industrial atmospheric concentrations of CO_2.

For each of these scenarios, two cases were developed to reflect higher and lower rates of economic growth. These variants are referred to as the Higher Growth and Lower Growth cases. Key assumptions for each scenario are provided in Table 3-1.

Also included is the EIS/AFOS Reference case, which has the most rapid buildup of greenhouse gas concentrations. *The IPCC has developed the EIS/AFOS Reference case and the 2030 Emissions case using baseline conditions that assume extrapolation of current trends and planned programs, while the remaining cases of 2060 Emissions, Control Policies, and Accelerated Policies assume some policy actions by the international community to reduce greenhouse gas emissions.* The differences among these cases can be illustrated best by comparing the global primary energy mix reflected in each scenario. As shown in Figure 3-1, the two "business-as-usual" scenarios indicate very rapid increases in energy demand, dominated primarily by the use of fossil fuels, particularly coal. Assuming that global policy actions are taken to respond to climate change, however, global energy demand grows much more slowly and is increasingly dominated by non-fossil fuels (Figure 3-2).

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TABLE 3-1

CHARACTERISTICS OF IPCC SCENARIOS

SCENARIO	Energy Supply[b]	Energy Demand[c]	Level of Greenhouse Gas Emission Controls[d]	CFC Status[e]	Deforestation[f]	Agriculture[g]
EIS/AFOS Reference Case[a]	Carbon-intensive	Business as usual	Modest; business as usual	Protocol/low compliance	Moderate	Current trends
2030 Emissions	Carbon-intensive	Business as usual	Modest; business as usual	Protocol/low compliance	Rapid/ Moderate	Current trends
2060 Emissions	Major switch to natural gas	High degree of energy efficiency	Stringent	Protocol/full compliance	Major reforestation	Current trends
Control Policies	Major phase-in of non-fossil sources	High degree of energy efficiency	Stringent	Total phaseout	Major reforestation	Declining factors
Accelerated Policies	Major phase-in of non-fossil sources	High degree of energy efficiency	Stringent	Total phaseout	Major reforestation	Declining factors

[a] Because the EIS/AFOS scenario was constructed with the aid of experts from many countries, the assumptions as defined here may not exactly match the specific descriptions provided below. However, the assumptions are qualitatively very similar to these specific descriptions.

[b] For the Carbon-intensive cases, energy supply is dominated by fossil fuel technologies. For the 2060 Emissions case, fossil fuels continue to play a major role, but the natural gas share of the energy supply market is increased. For the Control Policies case, non-fossil technologies become economic in the latter part of the next century and supply most primary energy needs after 2075. For the Accelerated Policies case, non-fossil technologies play a much larger role starting in the early part of the next century.

[c] In the Business as Usual cases, the annual rate of improvement in energy intensity (or primary energy use per dollar of GNP) decreases from an initial value between 1.0% and 1.5% to an average value of 0.7% to 1.2% for the years 2075 to 2100. The average annual rate of improvement in energy intensity for the years 1985 to 2100 ranges between 0.8% and 1.3%. In the High Degree of Energy Efficiency cases, the annual rate of improvement in energy intensity decreases from an initial value between 1.5% and 2.5% to an average value of 1.1% to 1.8% for the years 2075 to 2100. The average annual rate of improvement in energy intensity for the years 1985 to 2100 ranges between 1.2% and 1.9%.

(Notes continue on following page)

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NOTES FOR TABLE 3-1 (continued)

[d] In the Modest Controls cases, current emission control technologies are assumed. In the Stringent Controls cases, the following controls are assumed: more stringent NO_x and CO controls on mobile and stationary sources, including all gas vehicles using three-way catalysts (in OECD countries by 2000 and in the rest of the world by 2025); from 2000 to 2025 conventional coal burners used for electricity generation are retrofit with low NO_x burners, with 85% retrofit in the developed countries and 40% in developing countries; starting in 2000 all new combustors used for electricity generation and all new industrial boilers require selective catalytic reduction in the developed countries and low NO_x burners in the developing countries, and after 2025 all new combustors of these types require selective catalytic reduction; other new industrial non-boiler combustors such as kilns and dryers require low NO_x burners after 2000.

[e] In the Protocol/Low Compliance cases, the Montreal Protocol is assumed to come into force and apply through 2100, with 100% participation by the U.S. and developed countries and 85% participation by developing countries. The assumptions are the same in the Protocol/Full Compliance case except that all countries participate. In the Phaseout cases, CFCs and halons are completely phased out by 2000, and production of CCl_4 and CH_3CCl_3 are frozen with 100% participation.

[f] Tropical deforestation increases gradually in the Moderate case, from 11 million ha/yr in 1985 to 15 million ha/yr by about 2100. Tropical deforestation increases exponentially in the Rapid case, reaching 34 million ha/yr in about 2050, with almost complete tropical forest deforestation by about 2075. In the Reforestation cases, deforestation stops by 2025, and about 1,000 million ha are reforested by 2100.

[g] Levels of activity for the major agricultural activities were not varied among scenarios, because population levels were not varied. Emission factors, however, were changed among scenarios. Current estimates of average emission factors were used in the Current Trends cases, while reduced factors (assuming technological and management improvements) were used in the Declining Factors cases.

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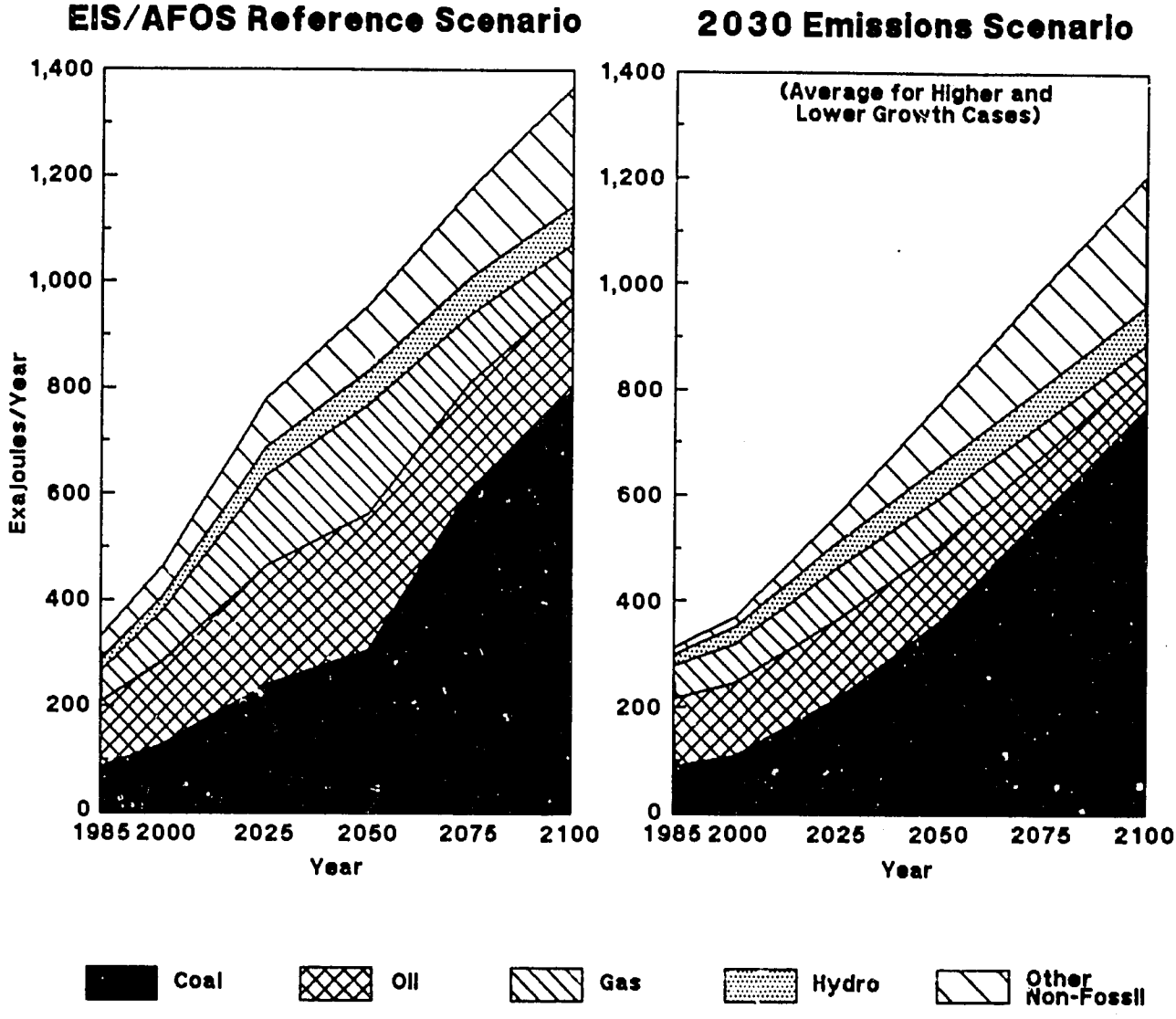
FIGURE 3-1

GLOBAL PRIMARY ENERGY MIX: BASELINE CASES



Sources: U.S./Japan Expert Group Report (1990);[1] Task A Report (1990).[2]

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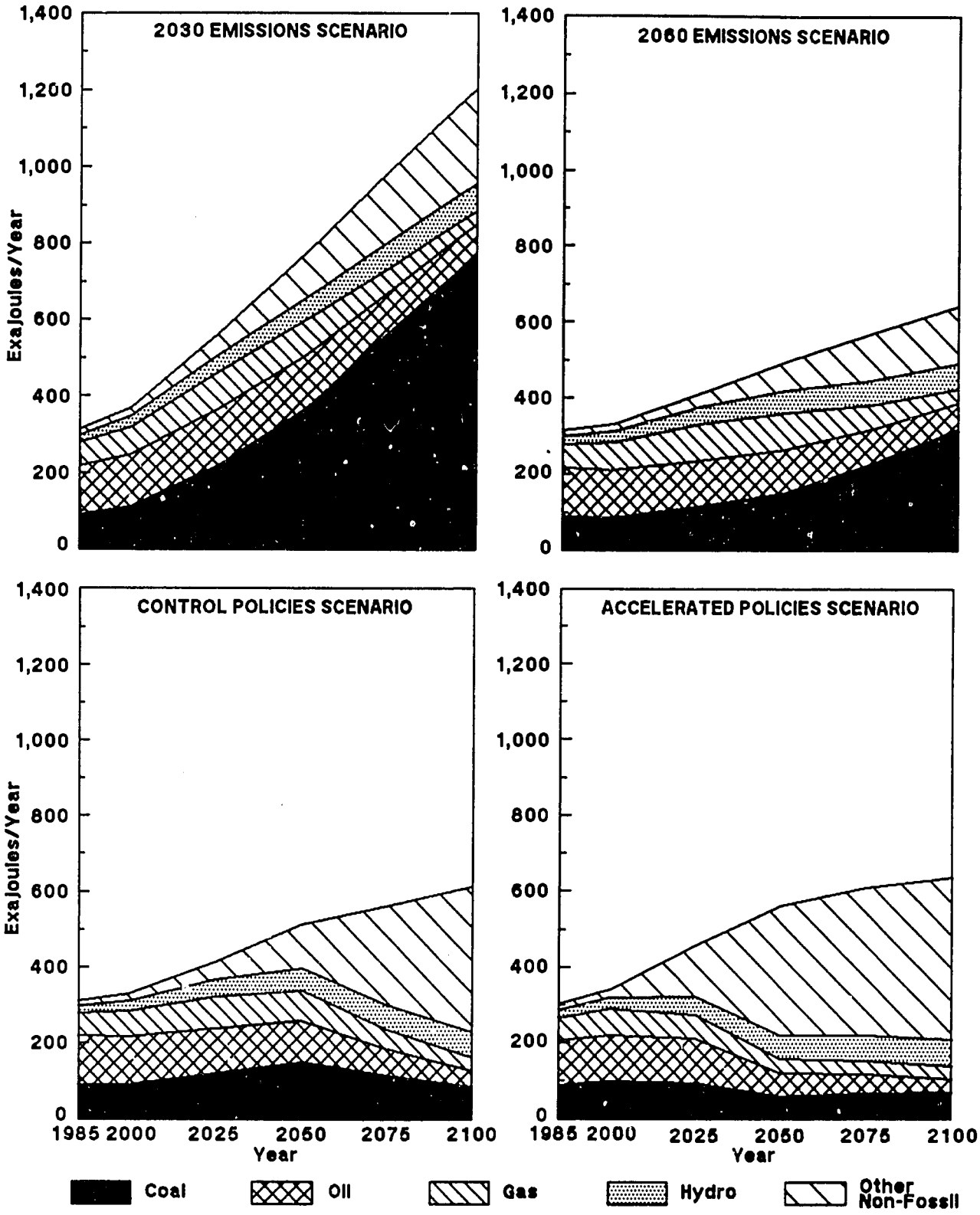
FIGURE 3-2

GLOBAL PRIMARY ENERGY MIX: TASK A SCENARIOS

(Average for Higher and Lower Growth Cases)



Source: Task A Report (1990).[2]

Projected emissions for all five scenarios and the resulting atmospheric concentrations are shown in Figure 3-3. Figure 3-3(b) shows the year when the atmospheric concentration of CO_2 reaches twice the pre-industrial level. This is an arbitrary level often used by climate experts. Its choice reflects a series of reviews by the National Academy of Sciences[3,4,5] that concluded that the sensitivity of the climate system to a doubling of CO_2 is probably in the range of 1.5 to 4.5°C. The rate and magnitude of climate change[6] associated with the cases in which few or no steps are taken to reduce emissions -- the EIS/AFOS Reference and 2030 Emissions cases -- represent a significantly greater climate threat to the global community than the policy cases -- 2060 Emissions, Control Policies, and Accelerated Policies.

3.2 EMISSIONS ASSUMING NO RESPONSE TO CLIMATE CHANGE

Greenhouse gas emissions from non-OECD countries will continue to rise rapidly if no policy actions are taken by the international community. The two base case scenarios -- the EIS/AFOS Reference case and the 2030 Emissions case -- illustrate this. A summary of the emissions from energy use, deforestation, CFC use, and agricultural activities by region and key countries is shown in Table 3-2 for 1985 and 2025. *For the base case, by 2025 the global share of greenhouse gas emissions from developing countries increases from one-third to one-half.* On a per capita basis, however, the developing countries still produce substantially less than the industrialized countries, e.g., 3-15 times less per capita than the U.S.

3.2.1 Emissions from Energy

Energy Emissions by Region

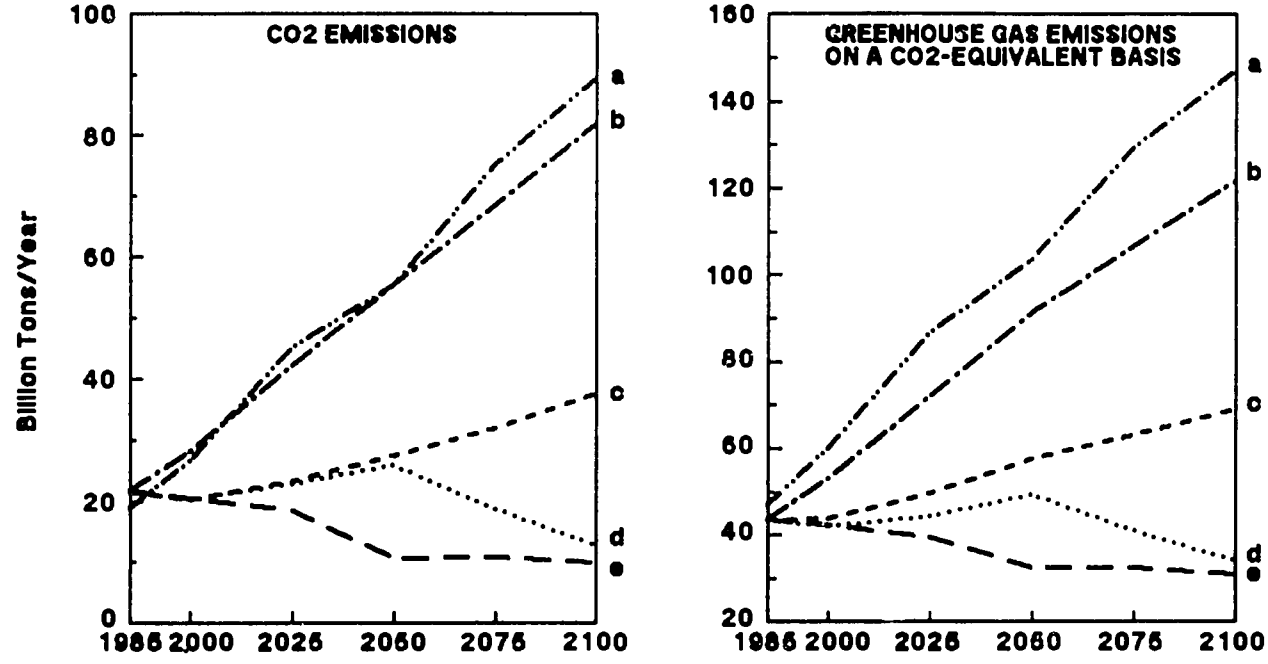
The largest source of greenhouse gas emissions is fossil fuels. In the IPCC scenarios, annual global primary energy supply increases from about 306 exajoules (EJ) in 1985 to 473 EJ (2030 Emissions/Lower Growth) and up to 737 EJ (EIS/AFOS Reference) by 2025.* Historically, global energy requirements have been met primarily with fossil fuels; in the IPCC scenarios presented here, where no actions to respond to climate change are assumed, fossil fuels continue to be the dominant energy source, supplying over 80% of total energy requirements through 2025. Energy consumption in the non-OECD countries follows a similar pattern as their economies and populations continue to expand: their percentage of global energy consumption increases from about 47% in 1985 to 59-66% by 2025 (Table 3-3).

* 1 Exajoule = 1 EJ = 10^{18} joules = 0.95 10^{15} Btus.

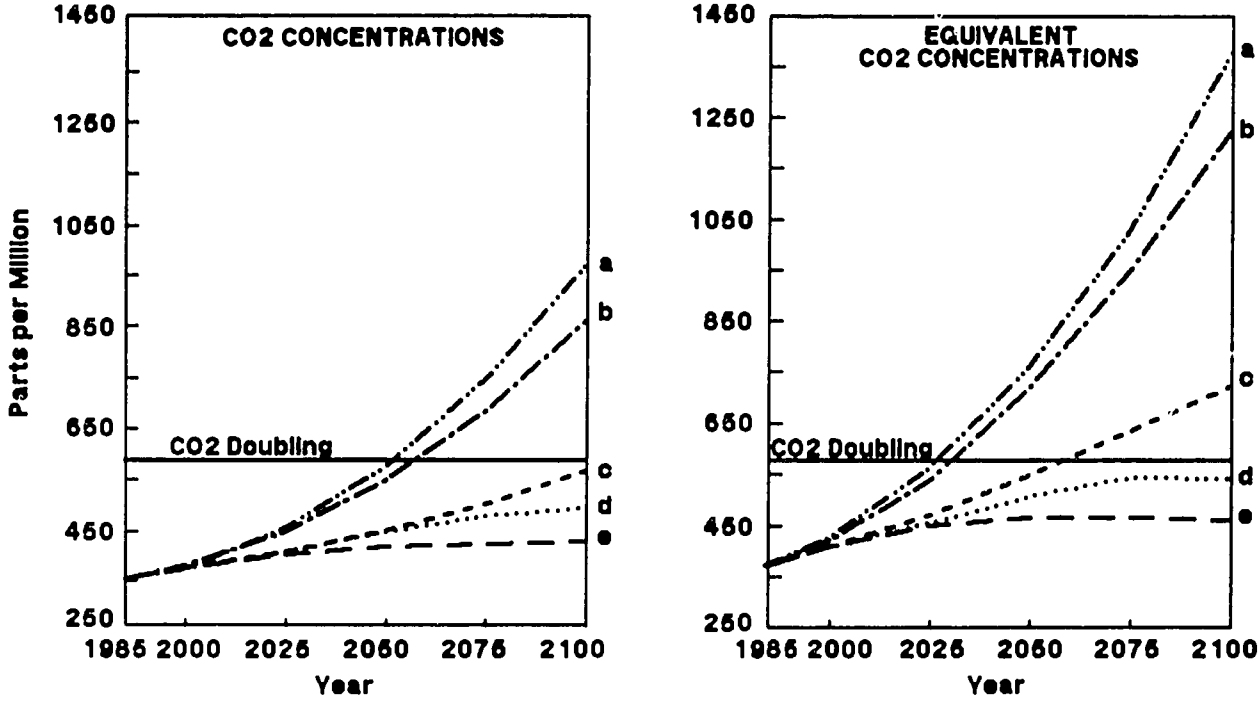
FIGURE 3-3

GREENHOUSE GAS EMISSIONS AND RESULTING ATMOSPHERIC CONCENTRATIONS

(a) Emissions



(b) Concentrations



(a) EIS/AFOS Reference Scenario (b) 2030 Emissions Scenario (c) 2050 Emissions Scenario
(d) Control Policies Scenario (e) Accelerated Policies Scenario

Sources: U.S./Japan Expert Group Report (1990);[1] Task A Report (1990).[2]

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TABLE 3-2

EMISSIONS FROM MAJOR GREENHOUSE-GAS-PRODUCING ACTIVITIES: BASELINE CASES
(million metric tons on CO_2-Equivalent Basis)

	CO_2 from Energy[a]		CO_2 from Deforestation		CFCs[b]		CH_4 from Rice		CH_4 from Animals		N_2O from Fertilizer		Total		Tons Per Capita	
	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025
United States	5,100	6,200-7,700	–	–	1,350	1,675	17	21	206	267	128	156	6,801	8,319-9,819	28	29-34
OECD Europe/Canada	2,900	4,000-5,100	–	–	1,275	2,340	15	15	311	397	136	268	4,637	7,020-8,120	11	14-17
OECD Pacific	1,100	1,500-2,200	–	–	510	935	38	27	97	168	11	16	1,756	2,646-3,346	12	16-20
Eastern Europe/USSR	5,100	8,400-10,300	–	–	710	1,735	34	38	277	344	142	266	6,263	10-783-12,683	15	21-25
Poland	436	935	–	–	–	–	–	–	–	–	–	–				
Centrally Planned Asia	1,900	3,700-7,300	220	250-660	90	650	674	687	145	279	139	230	3,168	5,796-9,806	3	3-6
China	1,844	6,303	–	–	–	–	561	571	134	254	129	211				
Middle East	400	1,800-2,600	–	–	40	275	13	17	21	59	11	27	485	2,178-2,978	4	8-11
Africa	700	700-2,900	620	660-1,210	200	1,400	55	116	107	277	25	95	1,707	3,248-5,998	3	2-4
Zaire	–	–	–	–	–	–	–	–	–	–	–	–				
Latin America	700	1,500-3,300	1,280	1,950-3,040	140	990	124	147	200	441	33	93	2,477	5,121-8,011	6	7-11
Brazil	150	473	–	–	–	–	86	78	57	92	8	14				
Mexico	249	730	–	–	–	–	2	4	23	63	13	46				
Rest of Central America	–	–	–	–	–	–	34	63	59	176	12	28				
South and East Asia	1,100	1,800-5,900	550	630-1,690	270	1,890	1,331	2,056	212	384	99	427	3,562	7,187-12,347	2	3-5
India	359	2,273	–	–	–	–	653	1,084	111	189	53	144				
Indonesia	81	517	–	–	–	–	153	302	10	23	12	155				
Pakistan	–	–	–	–	–	–	25	34	34	61	13	75				
Philippines	–	–	–	–	–	–	–	–	–	–	–	–				
Thailand	–	–	–	–	–	–	–	–	–	–	–	–				
World	19,100	29,700-45,500	2,670	3,500-6.600	4,580	11,890	2,297	3,124	1,576	2,617	723	1,580	30,946	52,411-71,311	6	6-9

NOTE: Several major emissions-producing activities are accounted for, but many of the smaller source categories identified in Table 2-2 are not included. Estimates for 2025 are taken from the 2030 Emissions scenario, except for the CO_2 estimates from energy, which also include the results from the EIS/AFOS Reference case. The emissions estimates for 1985 may differ slightly from the 1985 estimates presented in Chapter 2 since the estimates used in this chapter derive from a series of individual modelling analyses rather than from a single source such as U.N. Energy Statistics. The differences are generally very minor.

[a] The CO_2 emissions itemized in this table do not include emissions from cement production.

[b] Includes CFC-11, CFC-12, CFC-113, HCFC-22, CCl_4, CH_3CCl_3, and Halon 1301.

Sources: U.S./Japan Expert Group Report (1990);[1] Task A Report (1990).[2]

TABLE 3-3

ENERGY USE AND CO_2 EMISSIONS IN THE BASELINE SCENARIOS

REGIONS	ENERGY USE (EJ/yr) 1985	2025 EIS/AFOS Reference	2025 "2030 Emissions" Lower Growth	2025 "2030 Emissions" Higher Growth	CO_2 EMISSIONS (MMT/yr) 1985	2025 EIS/AFOS Reference	2025 "2030 Emissions" Lower Growth	2025 "2030 Emissions" Higher Growth	Tons CO_2/ Capita
United States	77.2	111	96.4	111.2	5,100	7,700	6,200	7,300	21-26
OECD Europe/Canada	62.9	103	77.1	91.7	2,900	5,100	4,000	4,800	8-11
OECD Pacific	19.2	39	22.1	24.9	1,100	2,200	1,500	1,500	9-13
Eastern Europe/USSR	74.9	166	128.5	143.2	5,100	10,300	8,400	9,900	17-19
Centrally Planned Asia	24.5	88	46.2	87.9	1,900	6,600	3,700	7,300	2-4
Middle East	7.7	43	28.6	34.4	400	2,600	1,800	2,200	6-9
Africa	8.7	46	12.8	31.6	700	2,900	700	2,200	0.5-2
Latin America	15.7	49	32.4	65.8	700	2,200	1,500	3,300	2-3
South and East Asia	15.1	92	28.6	66.4	1,100	5,900	1,800	4,400	0.7-2.4
TOTAL	305.9	737	472.7	657.1	19,100	45,500	29,700	42,900	4-6

Sources: U.S./Japan Expert Group Report (1990);[1] Task A Report (1990).[2]

As a result of major increases in fossil energy consumption, CO_2 emissions from energy activities in non-OECD countries increase from 9,800 million metric tons (MMT) CO_2 in 1985 to 17,900-29,300 MMT CO_2 by 2025. This increases the percentage of global CO_2 emissions attributable to energy activities in non-OECD countries from just over 50% in 1985 to 60-68% by 2025, depending on the scenario. On a per capita basis, however, the developed countries continue to produce much higher levels of CO_2 emissions: 8-26 tons CO_2/capita for the OECD countries; 17-19 tons CO_2/capita for Eastern Europe and the USSR; and 0.5-9 tons CO_2/capita for the developing countries.

Energy Emissions by Country

The only study for which analyses of greenhouse gas emissions from individual countries was provided was the EIS/AFOS Reference case. The study for China was prepared by government representatives on a preliminary basis, while the remaining country studies were prepared by independent experts and submitted to the IPCC for consideration at its proceedings. Table 3-4 summarizes major parameters for the key countries for which data were available.

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TABLE 3-4

SUMMARY RESULTS FROM THE EIS/AFOS REFERENCE CASE: KEY COUNTRIES

Country	GDP Growth (index) 1985	GDP Growth (index) 2025	Primary Energy (exajoules) 1985	Primary Energy (exajoules) EIS/AFOS 2025	Primary Energy (exajoules) AAGR[a] (%) 1985-2025	CO_2 Emissions (million tons CO_2) 1985	CO_2 Emissions (million tons CO_2) EIS/AFOS 2025	CO_2 Emissions (million tons CO_2) AAGR[a] (%) 1985-2025
Brazil	100	358	6.0	15.2	2.7	150	473	2.9
China[b]	100	877	29.0	86.0	2.8	1,844	6,303	3.0
India	100	669	8.1	36.6	3.8	359	2,273	4.0
Indonesia	100	332	1.8	9.3	4.2	81	517	4.4
Mexico	100	396	4.5	12.0	2.5	249	730	2.5
Poland	100	296	5.3	11.4	1.9	436	935	1.9

[a] AAGR - average annual growth rate in percent/year.

[b] China is not an A.I.D.-designed "key country," but is included because of its size.

Source: U.S./Japan Expert Group Report (1990).[1]

3.2.2 Emissions from Deforestation

The CO_2 emissions resulting from tropical deforestation are summarized in Table 3-5.* Deforestation from temperate regions is assumed to be balanced by reforestation. In both of the scenarios developed by the IPCC, rates of deforestation were developed only for the broad regional groupings of Latin America, Africa, and Asia; no country-specific estimates were presented.

3.2.3 Emissions from CFCs

CFCs are controlled under the terms of the Montreal Protocol, which requires significant reductions in the use of these chemicals to reduce the threat to the stratospheric ozone layer. CFC emissions are expected to be greatly reduced in the future, although the amount in use will depend on

* The level of CO_2 emissions from deforestation is subject to considerable uncertainty because of differing assumptions concerning the amount of carbon in the above-ground biomass and the use of the land after it is deforested, among other factors. For these scenarios the IPCC used a lower estimate of carbon stored in the biomass. For the EIS/AFOS scenario, a mid-range estimate was used beginning with 1985 emissions of CO_2 from deforestation at ca. 6,200 10^6 t CO_2. No regional estimates of deforestation were provided.

BRAZIL BASE CASE SCENARIO (1985-2025)

Electrification is expected to reach 100% in cities and 50% in rural area households. Based on historical trends, production levels for the industrial sector are held constant on a per capita basis. Brazilian industries are assumed to maintain the fuel switching flexibility instituted during the last few decades. Current trends in the mix of fuels are maintained, including a decline in the use of fuelwood, a modest rise in the use of natural gas and electricity, stabilization in the use of oil, and penetration of coal and charcoal in specific industrial end uses. Current trends in efficiency improvements continue based on the best technology available today in the Brazilian market. In the transport sector, the demand for increased mobility is satisfied with increased ownership of motorcycles.

Residential energy use grows at the slowest rate, with its share of final energy demand decreasing from 20% in 1985 to 12% by 2025. Transportation energy use grows at the fastest rate, from 1.2 EJ in 1985 to 3.8 EJ in 2025. Natural gas plays a much larger role, with major increases in residential use, industrial use, and electricity generation. Natural gas used for electricity generation grows from zero in 1985 to over 2 EJ in 2025 (34% of primary energy use for electricity generation). Hydro energy use increases from 1.9 EJ in 1985 to 3.4 EJ in 2025, although its share of electricity generation drops from 92% to 57%. As a result of these increases in primary energy use, CO_2 emissions grow from 150 MMT CO_2 in 1985 to 473 MMT CO_2 in 2025.

CHINA BASE CASE SCENARIO (1985-2025)

Population growth rate is 0.8%/yr. This assumes that the government's policy of holding growth to one child per family will succeed in the urban areas but not in the rural areas. Income per capita reaches $2,000 (U.S.) by 2025. Energy demand is increasing less rapidly than economic growth. The energy/GDP elasticity has been about 0.5 during much of the 1980s. About one-third of the reduction in energy intensity was achieved through a shift to production of less energy-intensive products. Despite these improvements, the unit energy consumption of most production processes remains inefficient. Steel production requires almost twice as much energy per unit of output as in the U.S. Similar disparities exist for other industrial goods, for space heating, and other end uses.

The base case scenario assumes that by 2025 China will achieve energy efficiencies comparable to those of the OECD today. Despite these improvements, domestic resources appear inadequate to meet projected energy demand. Coal production increases to about 2.9 billion tons/year, close to the total coal mined in the world today. Oil demand is sufficiently high to require oil imports and production of synthetic oil. The combustion of fossil fuels at this level is assumed to lead to serious environmental and capital availability problems. CO_2 emissions grow from 1,844 MMT in 1985 to 6,303 in 2025, slightly faster than growth in primary energy use. Industrial energy use continues to dominate final energy uses and increases its share of final energy use from 44% in 1985 to 50% in 2025. Transportation energy use increases at the fastest rate, from 1.3 EJ in 1985 to 8.4 EJ in 2025. Natural gas and nuclear energy increase their role by 2025, but coal continues as the dominant fuel, increasing its share of primary energy use from 58% in 1985 to 69% in 2025. Use of biomass declines from 6.6 EJ in 1985 to 3.4 EJ in 2025.

INDIA BASE CASE SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, GDP grows at an average annual rate of 4.9% from 1985 to 2025. The population growth rate is assumed to be 1.4%/year. This assumes that the government's policy of family planning will be moderately successful. Income per capita reaches $1,000 (U.S.) by 2025.

Recent history indicates that energy demand has increased somewhat faster than economic growth. This has led to a 40% increase in the energy/GDP ratio between 1970 and 1987. The increase was caused by substitution of biomass fuels by modern fuels and by increased use of oil for transportation and electricity for agriculture. The unit energy consumption of most production processes is much higher than that of the industrialized countries. For example, steel production requires almost twice as much energy per unit of steel output as that in the U.S. Similar differences exist for other industrial goods, household appliances, and other end uses. The potential for improving efficiency is substantial.

The scenario assumes that with efficiency improvements the energy intensity of the economy will decline to the same level as in 1984. Improvements in energy efficiency reduce unit energy consumption to below the levels seen in the industrialized countries today. Despite these improvements, the domestic resources of the country are inadequate to meet projected energy demand. Coal production increases to about 780 million tons, or about five times the amount mined in 1988. Oil demand is high enough to require increased oil imports, on the order of 5.8 million barrels of oil per year. The combustion of fossil fuels at this level is assumed to lead to serious environmental and capital availability problems.

Overall, primary energy grows at an annual rate of 3.8%, from 8.1 EJ in 1985 to 36.6 EJ in 2025. CO_2 emissions grow from 359 MMT CO_2 in 1985 to 2,273 MMT CO_2 in 2025. Most of the growth in final energy use is in the services, industrial, and transportation sectors, with energy use in the transportation sector growing from 0.9 EJ in 1985 to 7.3 EJ in 2025. The EIS/AFOS Reference case assumes only 15% improvement for the steel industry in India by 2025. Coal use grows from 32% of primary energy use in 1985 to 41% by 2025. Use of biomass, which accounts for 37% of primary energy in 1985, grows modestly through 2025 where it accounts for only 10% of primary energy use.

INDONESIA BASE CASE SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, GDP grows at an average annual rate of 3.0% from 1985 to 2025, with primary energy growing at an annual rate of 4.2% in the same period. Unlike the other developing countries, this represents an increase in energy intensity due in large part to a restructuring of the economy to include more energy-intensive industry. This is due to an explicit strategy of encouraging economic development through exploitation of domestic energy resources and basic materials for export of products rather than raw materials. CO_2 emissions increase from 81 MMT CO_2 in 1985 to 517 MMT CO_2 in 2025. In this time frame, use of biomass, while increasing, drops from 27% of primary energy in 1985 to 11% in 2025. Coal increases its share of primary energy from 2% in 1985 to 10% in 2025. The highest rate of growth is experienced in the transportation sector, which consumes 0.3 EJ in 1985 and 4.0 EJ in 2025 (over 48% of final energy use).

MEXICO BASE CASE SCENARIO (1985-2025)

GDP grows at an average annual rate of 3.5% from 1985 to 2025. The population growth rate during this period is 1.6% per year. The industrial sector is expected to shift towards non-energy-intensive manufacturing, although production levels per capita of some energy-intensive sectors continue to increase. Scarcity of natural gas is assumed to require increased use of fuel oil, except for power generation. In this sector, increased use of coal limits the contribution of local fossil fuels. Overall, primary energy grows at an annual rate of 2.5%, from 4.5 EJ in 1985 to 12.0 EJ in 2025. CO_2 emissions increase from 249 MMT CO_2 in 1985 to 730 MMT CO_2 in 2025. Growth in final energy use is highest in the industrial sector and lowest in the transportation sector. Use of biomass declines, while growth in the use of coal is the highest: from 0.14 EJ in 1985 to 1.2 EJ in 2025.

POLAND BASE CASE SCENARIO (1985-2025)

Poland is undergoing profound economic and environmental change. It is shifting from central planning to markets to allocate economic resources and attempting at the same time to conserve and protect environmental resources. The high energy intensity of the Polish economy, combined with heavy reliance on coal, has caused much of Poland's serious air and water pollution problems. One reason for the high energy intensity is the pervasive energy subsidies that discount the price of energy 25% to 80% below supply costs.

Almost 80% of Poland's primary energy is obtained from coal and lignite. However, coal resources are being depleted; the average heating value of coal used domestically has fallen from 24.1 gigajoules per ton (GJ/t) in 1978 to 22.5 GJ/t recently. Costs of producing coal have been increasing, presenting the nation with prospects of rising energy costs and energy shortages. Four sectors consume 80% of the energy used in the industrial sector: iron and steel (31%), chemicals (22%), food processing (16%), and building materials and ceramics (12%). Living space and automobile ownership is comparable to that in other Eastern European countries.

As a result of economic growth that averages 2.5% to 3.0% annually in the EIS/AFOS Reference scenario, primary energy use increases from 5.3 EJ in 1985 to 11.4 EJ in 2025, with growth in the building and transportation sectors slightly faster than in the industrial sector. Primary use of oil grows faster than coal or gas, increasing its share of primary energy use from 17% in 1985 to 24% in 2025. CO_2 emissions grow from 436 MMT CO_2 in 1985 to 935 MMT CO_2 in 2025.

TABLE 3-5

NET CO_2 EMISSIONS FROM TROPICAL DEFORESTATION (MMT CO_2/year)

REGION	1985	Rapid Deforestation 2000	Rapid Deforestation 2025	Moderate Deforestation 2000	Moderate Deforestation 2025
Latin America	1,280	2,160	3,040	1,720	1,950
Africa	620	840	1,210	660	660
Asia	770	1,250	2,350	880	880
TOTAL	2,670	4,250	6,600	3,260	3,500

Source: Task A Report (1990).[2]

the number of countries that sign the Protocol and the extent to which the signatories comply with its provisions. The emissions levels used by the IPCC are summarized in Table 3-6. CFCs have been used primarily by the industrialized nations. Under the terms of the Montreal Protocol, developing countries are entitled to increase their CFC usage to meet their industrial requirements. As a result, the share of emissions attributable to the developing countries is expected to increase from less than 20% in 1985 to nearly 50% by 2025 (on a CO_2-equivalent basis).

3.2.4 Emissions from Agriculture*

Estimates for emissions from agricultural activities were developed by the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) based on an IPCC-sponsored workshop held in December 1989 and subsequent discussions. Only one scenario that assumed no response to climate change was identified. In this scenario, the rates of greenhouse gas emissions per unit of agricultural activity (e.g., CH_4 emissions per hectare of land used for paddy rice cultivation) were assumed to remain constant over time. However, levels of agricultural activities (e.g., total area of land under paddy rice cultivation) changed through time as population and economic growth occurred. The specific emission estimates resulting from these assumptions are summarized in Table 3-7.

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TABLE 3-6

EMISSIONS FROM CFCs AND RELATED CHEMICALS: BASELINE CASES (MMT on a CO_2-Equivalent Basis)

REGION	CFC-11		CFC-12		Total CFCs	
	1985	2025	1985	2025	1985	2025
United States	170	65	790	520	1,350	1,675
OECD Europe/Canada	395	665	665	1,030	1,275	2,340
OECD Pacific	85	145	235	365	510	935
Eastern Europe/USSR	120	275	520	1,110	710	1,735
Poland	--	--	--	--	--	--
Centrally Planned Asia	20	85	60	450	90	650
China	--	--	--	--	--	--
Middle East	10	55	25	165	40	275
Africa	60	290	115	840	200	1,400
Zaire	--	--	--	--	--	--
Latin America	40	205	80	590	140	990
Brazil	--	--	--	--	--	--
Mexico	--	--	--	--	--	--
Rest of Central America	--	--	--	--	--	--
South and East Asia	75	355	165	1,185	270	1,900
India	--	--	--	--	--	--
Indonesia	--	--	--	--	--	--
Pakistan	--	--	--	--	--	--
Philippines	--	--	--	--	--	--
Thailand	--	--	--	--	--	--
World	975	2,140	2,655	6,260	4,580	11,890

NOTE: A dash (--) indicates information was not available.

Source: Task A Report (1990).[2]

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TABLE 3-7

EMISSIONS FROM MAJOR AGRICULTURAL ACTIVITIES: BASELINE CASES (MMT on a CO_2-Equivalent Basis)

REGION	CH_4 from Rice		CH_4 from Animals		N_2O from Fertilizer	
	1985	2025	1985	2025	1985	2025
United States	17	21	206	267	128	156
OECD Europe/Canada	15	15	311	397	136	268
OECD Pacific	38	27	97	168	11	16
Eastern Europe/USSR	34	38	277	344	142	266
Poland	–	–	–	–	–	–
Centrally Planned Asia	674	687	145	279	138	230
China	561	571	134	254	128	210
Middle East	13	17	21	59	11	27
Africa	55	116	107	277	25	95
Zaire	–	–	–	–	–	–
Latin America	124	147	200	441	33	93
Brazil	86	78	57	92	8	14
Mexico	2	4	23	63	13	46
Rest of Central America	34	63	59	176	12	28
South and East Asia	1,331	2,056	212	384	99	428
India	653	1,084	111	189	53	144
Indonesia	153	302	10	23	12	155
Pakistan	25	34	34	61	13	75
Philippines	–	–	–	–	–	–
Thailand	–	–	–	–	–	–
World	2,297	3,123	1,579	2,617	723	1,580

NOTE: A dash (–) indicates the information was not available.

Source: Task A Report (1990).[2]

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NOTES AND REFERENCES

1. See *An Integrated Analysis of Country Case Studies*, Report of the U.S./Japan Expert Group to the Energy and Industry Subgroup, Intergovernmental Panel on Climate Change, Forthcoming 1990. The non-OECD countries for which individual studies were included in this report are China, USSR, Poland, Hungary, India, the Republic of Korea, Indonesia, Mexico, Brazil, and Venezuela. Also see *Report of the Subgroup on Agriculture, Forestry, and Other Human Activities*, Draft Report and Draft Executive Summary, 1990.

2. These scenarios were designed to examine the implications of specific emission targets on economic growth, energy growth, and other factors if these targets were to be achieved. See *Emissions Scenarios of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change*, Task A Report of the U.S /Netherlands Expert Group on Emissions Scenarios, April 1990.

3. NAS (National Academy of Sciences). 1979. *Carbon Dioxide and Climate: A Scientific Assessment*. National Academy Press, Washington, D.C.

4. NAS (National Academy of Sciences). 1983. *Changing Climate*. National Academy Press, Washington, D.C. 496 pp.

5. NAS (National Academy of Sciences). 1987. *Current Issues in Atmospheric Change*. National Academy Press, Washington, D.C.

6. There are many excellent reviews of the science of climate change. For example, see U.S. EPA 1989. *Policy Options for Stabilizing Global Climate*. Draft Report to Congress.

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CHAPTER 4

ALTERNATIVE APPROACHES TO CONTROLLING GREENHOUSE GAS EMISSIONS WHILE MAINTAINING VIGOROUS ECONOMIC GROWTH

SUMMARY

Significant potential exists for reducing greenhouse gas emissions in developing countries by 2025. The basis for the discussions on the potential reductions are three policy-driven scenarios -- the 2060 Emissions case, the Control Policies case, and the Accelerated Policies case. Emissions from energy-related activities would likely be reduced through a combination of energy efficiency measures, a shift to non-fossil energy supplies, and greater reliance on less carbon-intensive fossil fuels. Concurrently, tropical deforestation would be expected to stop through aggressive reforestation; technological and management improvements in agricultural activities would significantly lower emissions, and a reduction in CFC use is anticipated through full compliance with the Montreal Protocol and a total phaseout of the major CFCs.

4.1 INTRODUCTION

This chapter discusses the potential reductions in emissions that the international community, particularly the developing countries, may be able to achieve while maintaining economic growth. The basis for the discussion is the set of three policy-driven scenarios analyzed by the RSWG (Response Strategies Working Group) of the IPCC in its Task A Report -- the "2060 Emissions", "Control Policies", and "Accelerated Policies" cases.* In addition to these scenarios, policy studies on several developing countries are included. These individual country studies have been developed by independent experts for the IPCC as potential policy responses using the EIS/AFOS Reference scenario as a baseline. The individual country studies presented here are preliminary and do not reflect official government positions. They are presented to provide additional insight into the potential effect of alternative policy responses.

4.2 EMISSIONS ASSUMING POLICY RESPONSES TO CLIMATE CHANGE

Greenhouse gas emissions have been converted to a common (carbon dioxide) basis, and are presented in Table 4-1 by region and activity for 1985 and 2025. Data for the year 2025 reflect

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* The 2060 Emissions scenario is treated as a policy case in this discussion. The IPCC designed the scenario to achieve a doubling of CO_2 by 2060 without specifying whether it was a policy case or not. The IPCC did, however, indicate that the level of greenhouse gas emissions reflected in the scenario may not be achievable without government intervention. Therefore, we treat this case as a policy scenario, although it could also be viewed as a low emissions, business-as-usual case.

TABLE 4-1

EMISSIONS FROM MAJOR EMISSIONS-PRODUCING ACTIVITIES: POLICY CASES
(million metric tons on CO_2-Equivalent Basis)

	CO_2 from Energy		CO_2 from Deforestation		CFCs		CH_4 from Rice		CH_4 from Animals		N_2O from Fertilizer		Total		Tons Per Capita	
	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025
United States	5,100	2,933-4,767	–	–	1,350	1,595-2,435	17	19	206	216	128	121	6,801	4,884-7,558	28	20-32
OECD Europe/Canada	2,900	2,567-3,300	–	–	1,275	420-1,395	15	13	311	330	136	220	4,637	3,550-5,258	11	8-12
OECD Pacific	1,100	733-1,100	–	–	510	310-670	38	23	97	136	11	13	1,756	1,215-1,942	12	8-13
Eastern Europe/USSR	5,100	3,667-6,233	–	–	710	170-715	34	32	277	281	142	218	6,263	4,368-7,479	15	11-18
Poland	436	–	–	–	–	–	–	–	–	–	–	–				
Centrally-Planned Asia	1,900	3,667-5,133	220	-116	90	20-90	674	561	145	235	139	188	3,168	4,555-6,091	3	4-5
China	1,844	–	–	–	–	–	561	466	134	214	129	172				
Middle East	400	733-1,467	–	–	40	10-40	13	13	21	48	11	22	485	826-1,590	4	7-14
Africa	700	367-1,467	620	-290	200	55-210	55	94	107	231	25	78	1,707	535-1,790	3	1-3
Zaire	–	–	–	–	–	–	–	–	–	–	–	–				
Latin America	700	733-1,833	1,280	-1,100	140	40-145	124	120	200	363	33	76	2,477	232-1,437	6	0.4-3
Brazil	150	–	–	–	–	–	86	63	57	76	8	11				
Mexico	249	–	–	–	–	–	2	2	23	52	13	38				
Rest of Central America	–	–	–	–	–	–	34	52	59	145	12	23				
South and East Asia	1,100	1,833-2,933	550	-174	270	70-280	1,331	1,682	212	336	99	350	3,562	4,097-5,407	2	3-4
India	359	–	–	–	–	–	853	886	111	168	53	118				
Indonesia	81	–	–	–	–	–	153	246	10	19	12	127				
Pakistan	–	–	–	–	–	–	25	27	34	52	13	15				
Philippines	–	–	–	–	–	–	–	–	–	–	–	–				
Thailand	–	–	–	–	–	–	–	–	–	–	–	–				
World	19,100	17,233-28,233	2,670	-1,680	4,580	2,690-5,975	2,297	2,554	1,576	2,178	723	818	30,856	24,262-38,552	6	5-8

NOTE: All estimates are taken from the 2060 Emissions, Control Policies, and Accelerated Policies cases in the Task A Report.

Source: Task A Report (1990).[1]

the range of projected emissions associated with the three policy scenarios. Figures 4-1 and 4-2 compare the policy cases with the baseline cases on a regional basis. Figure 4-1 shows the regional changes in emissions from the major greenhouse-gas-producing activities as a result of policy actions; Figure 4-2 shows the regional changes in per capita emissions.

4.2.1 Emissions from Energy Use

Energy Emissions Globally and by Region

Greenhouse gas emissions from energy-related activities can be reduced through a combination of energy efficiency measures, shifts to non-fossil fuel energy supplies, and greater use of natural gas. (See Table 4-1 and Figure 4-3). In the three policy scenarios, global primary energy supply increases from 306 EJ in 1985 to a range of 374 EJ (2060 Emissions/Lower Growth) to 527 EJ (Accelerated Policies/Higher Growth) in 2025. This compares with a range of 473-737 EJ by 2025 in the baseline cases. While the percentage of energy requirements supplied by fossil fuels in the baseline cases was over 80% in all cases, the percentage attributable to fossil fuels in the policy cases declines to as low as 53% by 2025 (Accelerated Policies/Higher Growth).

The overall impact on emissions of these policy actions to change energy use patterns is a significant reduction in global CO_2 emissions compared to the baseline cases (Figure 4-4). In these policy scenarios the portion attributable to non-OECD countries increases as in the baseline scenarios, but the level of emissions are much lower: CO_2 emissions increase from the 1985 level of 9,800 million metric tons (MMT) CO_2 to a range of 11,400-18,700 MMT CO_2 by 2025 compared to 17,900-29,300 MMT CO_2 in the baseline cases.

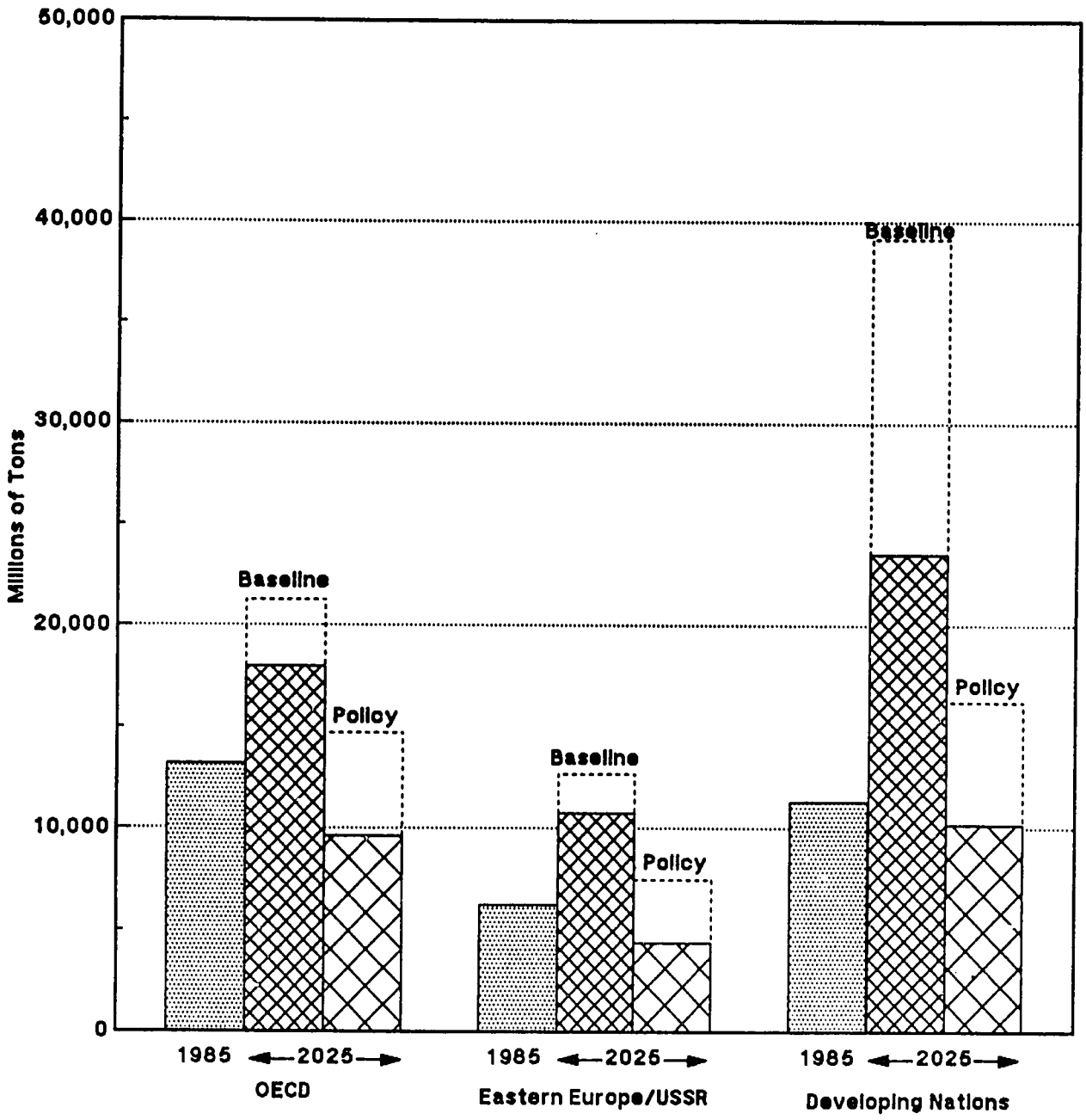
Energy Emissions in Key Countries

The key country summary presented here is taken from the individual country studies developed for the IPCC. These studies have been developed by independent experts and do not reflect official positions of the respective governments. The policy options analyzed by the IPCC for these countries focus primarily on structural economic changes, reductions in energy consumption, decreased conversion losses when generating electricity, and shifts to less carbon-intensive fuels. Figure 4-5 shows the changes in CO_2 emissions for the key countries as a result of policy actions. These policy options result in a substantial reduction of CO_2 emissions in several key countries. In Poland and Brazil, emissions are reduced by more than one-half and between one-quarter and one-half in India, China, Indonesia, and Mexico. Key county data are summarized below in the shaded boxes.

FIGURE 4-1

COMPARISON OF EMISSIONS FROM MAJOR GREENHOUSE GAS-PRODUCING ACTIVITIES: BASELINE AND POLICY CASES

(Millions of Tons on a CO2-Equivalent Basis)



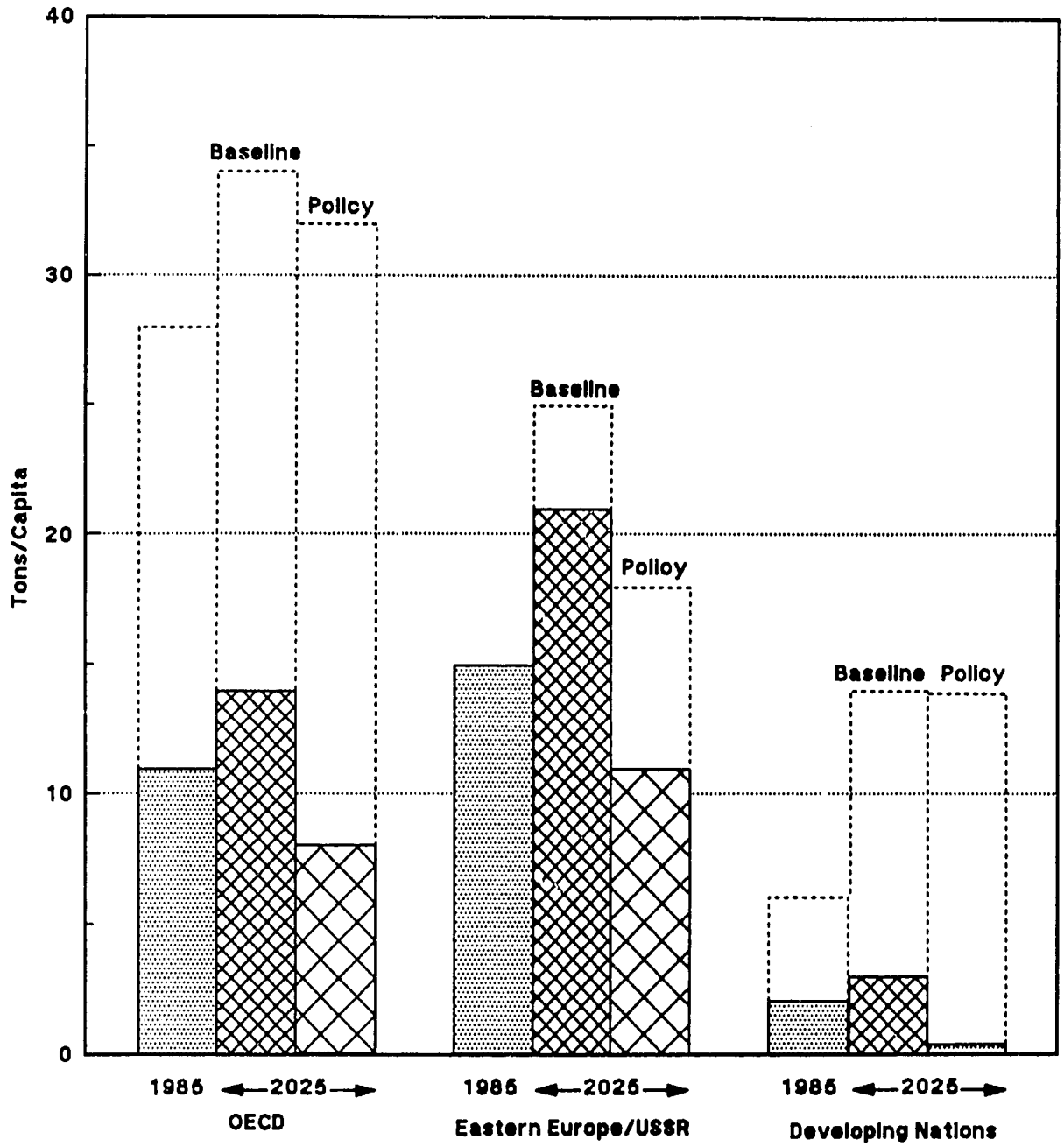
NOTE: The dotted portions represent the range of uncertainty in the IPCC scenarios.

Source: Task A Report (1990).[1]

FIGURE 4-2

COMPARISON OF AVERAGE PER CAPITA EMISSIONS FROM MAJOR GREENHOUSE GAS-PRODUCING ACTIVITIES: BASELINE AND POLICY CASES

(Tons Per Capita on a CO2-Equivalent Basis)



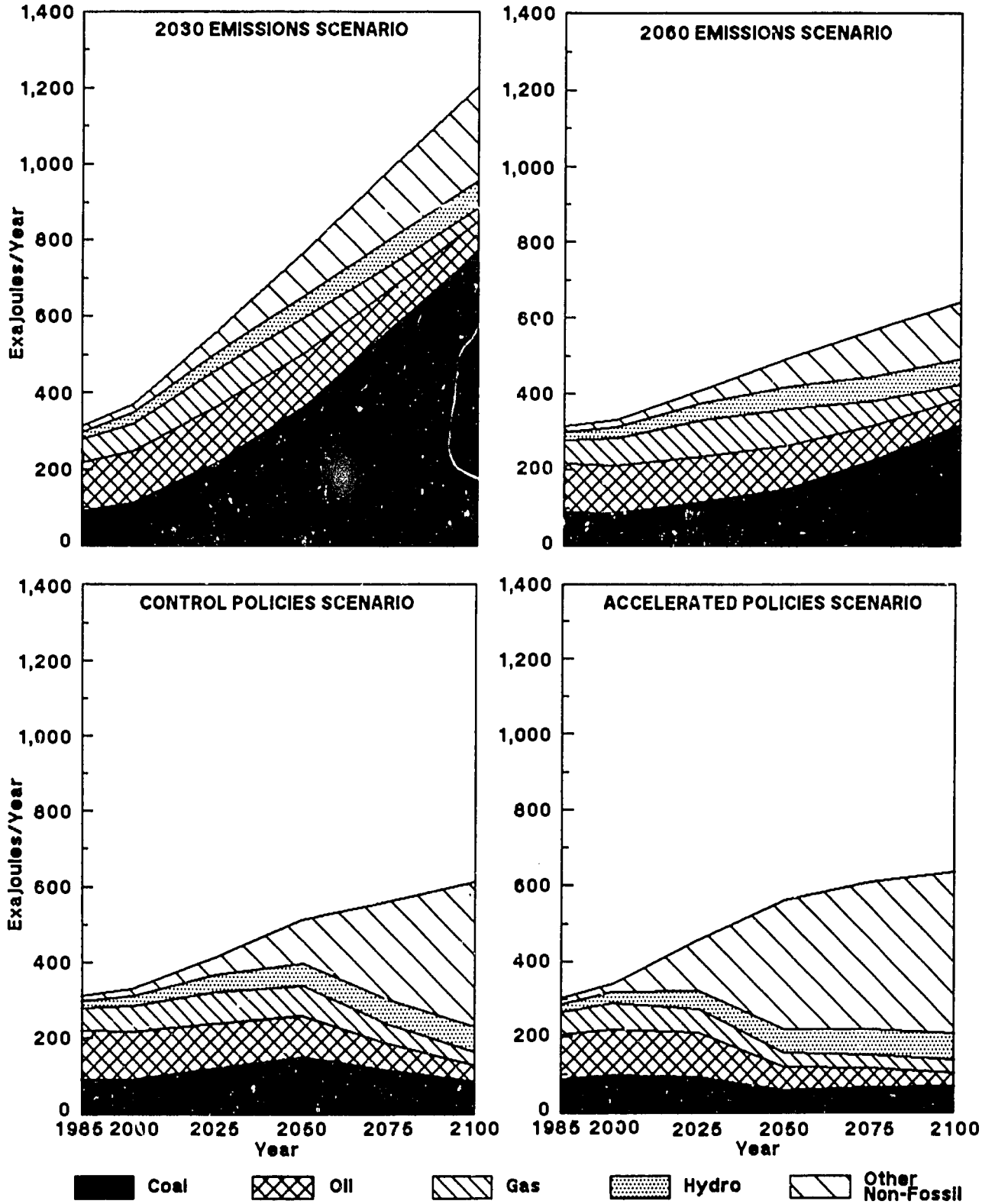
NOTE: The dotted portions represent the differences within the region, e.g., for 1985 in the OECD the lower estimate of 11 tons/capita is for Western Europe/Canada; the upper end of the range is 28 tons/capita for the U.S. (see Table 4-1).

Source: Task A Report (1990).[1]

FIGURE 4-3

GLOBAL PRIMARY ENERGY MIX: TASK A SCENARIOS

(Average for Higher and Lower Growth Cases)

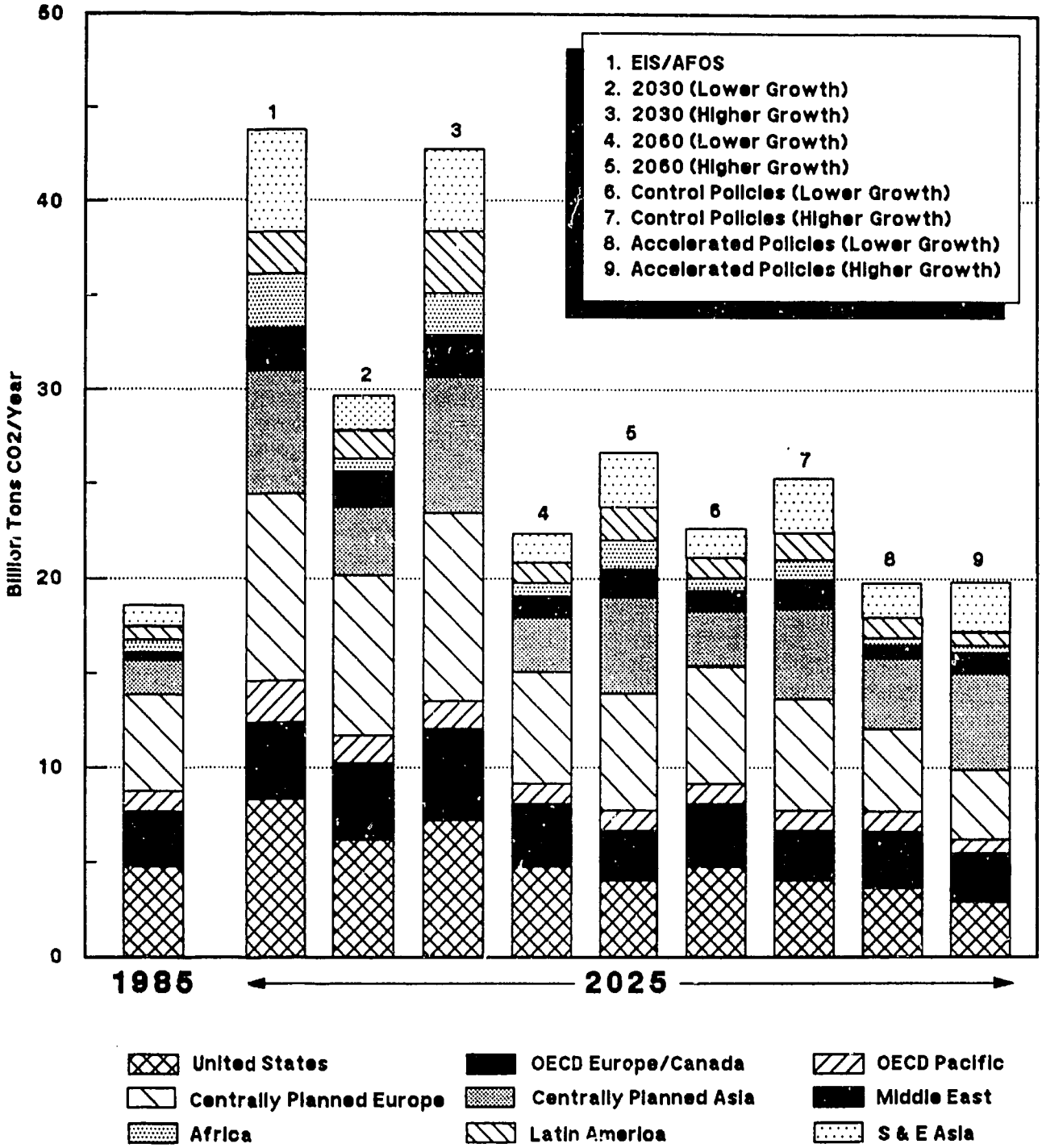


Source: Task A Report (1990).[1]

FIGURE 4-4

CO2 EMISSIONS FROM FOSSIL FUELS BY REGION

(Billion Tons CO2/Year)

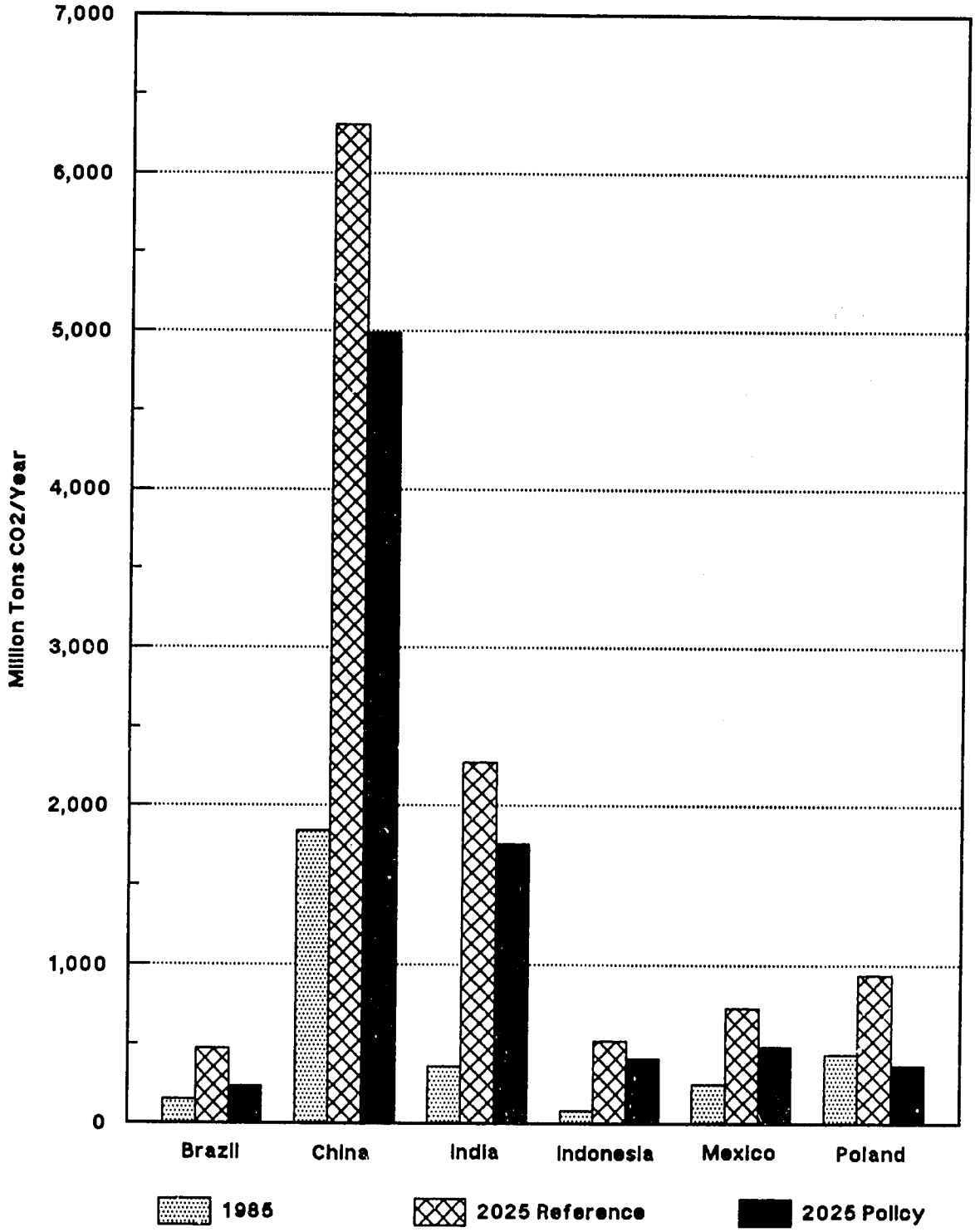


Sources: Task A Report (1990);[1] U.S./Japan Expert Group (1990).[2]

FIGURE 4-5

CARBON DIOXIDE EMISSIONS FROM ENERGY USE IN KEY COUNTRIES

(Million Tons CO2/Year)



Sources: U.S./Japan Expert Group (1990).[2]

BRAZIL POLICY SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, primary energy use grows from 6.0 EJ in 1985 to 15.2 EJ in 2025, with CO_2 emissions growing from 150 MMT CO_2 to 473 MMT CO_2. The IPCC study analyzed the potential to reduce growth in primary energy by 61%, resulting in energy use of 9.6 EJ in 2025, and to reduce growth in CO_2 emissions by 75% to 231 MMT CO_2 in 2025.* *Specifically, energy efficiency and conservation are estimated to decrease growth in final energy demand by 65%.* Technological efficiency is assumed to reach the level of the best currently available in the world market. Increasing the size of appliances offsets part of the efficiency improvement in households. Natural gas use is expected to expand to heat production processes in all the sectors. Development of natural gas grids in larger cities allows the substitution of gas for electricity and LPG in water heating and cooking. Use of biomass (i.e., alcohol) for transportation is expected to increase beyond current government plans. *Growth in demand for electricity is estimated to be reduced by 60%;* combined with increases in efficiency of electricity generation, this results in a 58% decrease in the growth of energy used for electricity generation, most of which is in fossil fuel use. Hydropower is estimated to provide 85% of the generation, an increase from 50% compared to the EIS/AFOS Reference scenario. Even at this higher share of total generation, the total amount of hydropower required was less than in the EIS/AFOS Reference scenario.

CHINA POLICY SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, primary energy use was assumed to increase from 29 EJ in 1985 to 86 EJ in 2025, with CO_2 emissions increasing from 1,844 MMT CO_2 to 6,303 MMT CO_2 during this same period. The policy objectives identified by the IPCC are assumed to reduce the growth in primary energy use by 22%, resulting in energy use of 73.2 EJ in 2025, and to reduce the growth in CO_2 emissions by 30%, resulting in emissions of 4,987 MMT CO_2 in 2025. *Policies in China are aimed at reducing emissions from energy use, including improved unit energy consumption and fuel switching.* Reductions in the growth in coal use are greater than total reductions in primary energy use and occur in the industrial sector, for electricity generation, and for synfuels production. These reductions in coal use are partially offset by increases in oil imports, nuclear energy, and hydro energy.

* The IPCC study participants did not evaluate specific policies, but analyzed the potential to achieve reductions in emissions. The specific policies that would need to be adopted to achieve the objectives evaluated by the IPCC require further analysis.

INDIA POLICY SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, primary energy use was estimated to increase from 8.1 EJ in 1985 to 36.6 EJ in 2025, with CO_2 emissions increasing from 359 MMT CO_2 to 2,273 MMT CO_2 during this period. *The policy objectives evaluated by the IPCC study participants reduce the growth in primary energy use by 27%*, resulting in energy use of 29.0 EJ in 2025, and also reduce the growth in CO_2 emissions by 27%, resulting in emissions of 1,760 MMT CO_2 in 2025. *Key policy objectives include improvements in unit energy consumption and fuel switching.* Additional improvements are assumed to be possible in the industrial sector through policies that address some of the historical factors that may have constrained efficiency improvements, including government ownership of all large infrastructure industries, the higher energy-consuming characteristics of imported technology, and fundamental characteristics of inputs (e.g., reliance on iron ore rather than scrap steel and the poorer-quality coals that are often utilized). Additional improvements are assumed to be possible through programs to promote the use of more efficient stoves in urban areas, which would then spread to rural areas. Decreases in demand for electricity would reduce growth in energy use for electricity generation by 22%, mostly through reductions in coal-fired generation. Natural gas is assumed to be used more extensively.

INDONESIA POLICY SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, primary energy increased from 1.8 EJ in 1985 to 9.3 EJ in 2025, which increased CO_2 emissions from 81 MMT CO_2 in 1985 to 517 MMT CO_2 in 2025. In the policy case, *policies are aimed at reducing emissions and include improved unit energy consumption and fuel switching.* Growth in primary energy use by 2025 is assumed to be reduced 21% and growth in CO_2 emissions by 25%. *Half of the reductions in energy use is in the transportation sector* and a quarter is in the industrial sector. Growth in coal and oil use is reduced 57% and 33%, respectively, while natural gas is used more extensively.

MEXICO POLICY SCENARIO (1985-2025)

In the EIS/AFOS Reference scenario, primary energy was assumed to increase from 4.5 EJ in 1985 to 12.0 EJ in 2025; CO_2 emissions increased from 249 MMT CO_2 in 1985 to 730 MMT CO_2 in 2025. The IPCC study participants identified policies that would reduce growth in primary energy use by 39% and growth in CO_2 emissions by 50%. *Most of the reductions were estimated to occur in the residential sector, where growth in final energy use was reduced by 80%*, primarily through the diffusion of efficient lighting and solar water heaters, *and in the transportation sector*, where reductions below 1985 levels were assumed to occur. Energy use in the industrial sector is affected very little. Hydro energy, which grows from 0.2 EJ to 0.5 EJ in the EIS/AFOS Reference scenario, is used more extensively, growing to 1.0 EJ in 2025. Increases in coal use are reduced by 71%, and the use of natural gas increases by 0.2 EJ in 2025 compared with the EIS/AFOS Reference scenario.

POLAND POLICY SCENARIO (1985-2025)

The current energy saving potential has been estimated at 40% of current energy use. Opportunities to improve energy efficiency in steel production include adoption of continuous casting, continuous hot rolling and finishing lines, replacement of open hearth furnaces by the basic oxygen furnaces, and proper use of electric arc furnaces. In building materials production, opportunities include replacement of wet process cement kilns with semi-dry and dry processes, broader use of enormous supplies of ash from power stations as a cement additive, full recycling of glass scrap, and better management of direct-fired processes in ceramics manufacture. In food processing, potentials include switching from coal boilers to oil and gas. Major improvements can be realized by improving the thermal performance of buildings.

Structural changes in the economy would likely yield major reductions in energy intensity and could be achieved at costs that are negative or zero. Such changes include a structural shift towards less material-intensive sectors and *new energy price mechanisms that stimulate technical energy efficiency improvements* and eliminate some segments of heavy, energy-intensive industry. Natural gas can be expected to play a larger role as coal prices increase from elimination of price subsidies. Structural changes in the economy alone are estimated to reduce the growth in CO_2 emissions by over 75%, reducing CO_2 emissions in 2025 to 550 MMT CO_2, compared with 935 MMT CO_2 in the EIS/AFOS Reference case. Additionally, specific steps to reduce emissions, primarily energy efficiency policies, could leave emissions levels virtually constant at current levels of 440 MMT CO_2 at minimal cost. Additional reductions in CO_2 emission levels by 2025, to 20% below current levels, could possibly be achieved through response measures that include major shifts in fossil energy supply through interfuel substitution and major reductions in primary energy demand due to higher energy quality and energy conservation.

4.2.2 Emissions From Deforestation

Although current deforestation is a source of CO_2 emissions, *in principle* it is possible to reverse this trend and transform the world's forests from a net source to a net sink of carbon if deforestation can be stopped. The IPCC evaluated only one scenario that reverses current deforestation trends. Under this scenario, tropical deforestation is assumed to stop by 2025, and about 1 billion hectares (ha) are reforested by 2100.* The reforestation scenario analyzed by the IPCC estimated reforestation for three broad regional levels only -- the tropical areas of Latin America, Africa, and Asia. The rates of reforestation are presented in Table 4-2.

4.2.3 Emissions from CFCs

Total CFC use is currently being reduced under the terms of the Montreal Protocol. In the baseline cases it was assumed that there would be a relatively low level of compliance with the Protocol.

* The temperate regions of the world are assumed to be in balance; that is, carbon emissions from deforestation are assumed to equal uptake of carbon from reforestation.

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TABLE 4-2

NET CO_2 EMISSIONS FROM TROPICAL DEFORESTATION AND REFORESTATION (MMT CO_2/year)

REGION	1985	Rapid Deforestation 2000	Rapid Deforestation 2025	Moderate Deforestation 2000	Moderate Deforestation 2025	Reforestation 2000	Reforestation 2025
Latin America	1,280	2,160	3,040	1,720	1,950	-950	-1,100
Africa	620	84	1,210	660	660	-40	-290
Asia	770	1,250	2,350	880	880	-70	-290
TOTAL	2,670	4,250	6,600	3,260	3,500	-840	-1,680

Source: Task A Report (1990).[1]

In response to increased concern over stratospheric ozone depletion and the greenhouse impact of CFCs, the policy cases evaluated full compliance with the terms of the Montreal Protocol and a total phaseout of the major CFCs. The emissions resulting from these policy actions are summarized by region in Table 4-3. Total world CFC levels in 2025 could be reduced significantly from 1985 or might increase by as much as 30%; in 1985 the OECD countries represented 68% of the world's total CFC emissions.

4.2.4 Emissions From Agriculture

Only the Task A scenarios included an emissions scenario for agricultural activities that assumed policy actions would be taken to reduce agriculture-related emissions. This scenario did not alter the levels of agricultural activity discussed in the previous chapter; that is, the amount of land under paddy rice cultivation, nitrogen fertilizer use, and meat and dairy production were assumed to remain constant. However, technological and management improvements that were assumed lowered the rate of emissions from agricultural activities. Table 4-4 summarizes the impact of these policies on emissions from agricultural activities. It shows that policy actions by 2025 with respect to methane production from rice might be effective in holding down the rate of increase of world methane production; similarly, policy actions could reduce N_2O production from fertilizers, but would be less effective in reducing methane production from animals.

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TABLE 4-3

EMISSIONS FROM MAJOR CFCS AND RELATED CHEMICALS: POLICY CASES (MMT on a CO_2-Equivalent Basis)

REGION	CFC-11		CFC-12		Total CFCs	
	1985	2025	1985	2025	1985	2025
United States	170	6-137	790	22-606	1,350	1,595-2,435
OECD Europe/Canada	395	15-323	665	19-509	1,275	420-1,395
OECD Pacific	85	3-70	235	7-180	510	310-670
Eastern Europe/USSR Poland	120	4-96	520	15-400	710	170-715
Centrally Planned Asia China	20	1-14	60	2-48	90	20-90
Middle East	10	1-10	25	1-17	40	10-40
Africa Zaire	60	2-49	115	3-89	200	55-210
Latin America Brazil Mexico Rest of Central America	40	2-34	80	2-63	140	40-145
South and East Asia India Indonesia Pakistan Philippines	75	3-60	165	5-126	270	70-280
World	975	37-794	2,655	74-2,037	4,580	2,690-5,975

NOTE: High end of the ranges in 2025 reflects full compliance with the Montreal Protocol; low end assumes complete phaseout of major ozone-depleting chemicals.

Source: Task A Report (1990).[1]

TABLE 4-4

EMISSIONS FROM AGRICULTURAL ACTIVITIES: TASK A REPORT (MMT/year on a CO_2-equivalent basis)

REGION	CH_4 from Rice			CH_4 from Animals			N_2O from Fertilizer		
	1985	2025 Baseline	2025 Policy	1985	2025 Baseline	2025 Policy	1985	2025 Baseline	2025 Policy
United States	16.8	21.0	18.9	205.8	266.7	216.3	128.1	156.3	120.8
OECD Europe/Canada	14.7	14.7	12.6	310.8	396.9	329.7	135.8	268.0	219.6
OECD Pacific	37.8	27.3	23.1	96.6	168.0	136.5	10.9	16.4	13.2
Eastern Europe/USSR	33.6	37.8	31.5	277.2	344.4	281.4	141.7	266.1	217.8
Poland	–	–	–	–	–	–	–	–	–
Centrally Planned Asia	674.1	686.7	560.7	144.9	279.3	235.2	138.5	230.1	188.2
China	570.7	571.2	466.2	134.4	254.1	214.2	128.5	210.5	172.3
Middle East	12.6	16.8	12.6	21.0	58.8	48.3	10.9	27.3	22.3
Africa	54.6	115.5	94.5	107.1	277.2	231.0	24.6	95.2	77.9
Zaire	–	–	–	–	–	–	–	–	–
Latin America	123.9	147.0	119.7	199.5	441.0	363.3	33.3	93.4	76.5
Brazil	86.1	77.7	63.0	56.7	92.4	75.6	7.7	14.1	11.4
Mexico	2.1	4.2	2.1	23.1	63.0	52.5	12.8	46.0	37.8
Rest of Central America	33.6	63.0	52.5	58.8	176.4	144.9	11.8	28.2	23.2
South and East Asia	1,331.4	2,055.9	1,682.1	212.1	384.3	336.0	99.0	427.5	349.5
India	653.1	1,083.6	886.2	111.3	189.0	165.0	52.9	144.5	118.5
Indonesia	153.3	302.4	245.7	10.5	23.1	18.9	12.3	155.4	127.1
Pakistan	25.2	33.6	27.3	33.6	60.9	52.5	13.2	74.7	15.5
Philippines	–	–	–	–	–	–	–	–	–
World	2,297	3,123	2,554	1,579	2,617	2,178	723	1,578	818

NOTE: A dash (–) indicates that information was not available.

Source: Task A Report (1990).[1]

NOTES AND REFERENCES

1. Task A Report. 1990. *Emissions Scenarios of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change*. Draft Report of the U.S./Netherlands Expert Group (Task A). 7-8 April, 1990.

2. U.S./Japan Expert Group Report. 1990. *An Integrated Analysis of Country Case Studies*. Draft Report of the U.S./Japan Expert Group to the Energy and Industry Subgroup of the Intergovernmental Panel on Climate Change. Forthcoming 1990.

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CHAPTER 5

STRATEGIC OPTIONS TO CONTROL GREENHOUSE GAS EMISSIONS WHILE MAINTAINING ECONOMIC GROWTH

SUMMARY

The U.S. and other OECD countries are likely to account for a declining share of future greenhouse gas emissions, while the rapidly industrializing developing regions will contribute a substantially greater share over the next three to five decades. Thus, a major focus in developing countries must be promotion of demand-side measures that increase efficiency, and supply-side measures that promote inter-fuel substitution by less carbon-intensive fuels together with increased efficiency in fuel conversion. Other strategic options include promotion of sustainable agricultural practices and agroforestry, tropical forestry strategies such as natural forest management to improve the productivity of existing natural forests and plantations, and a variety of agricultural management options to reduce greenhouse gas emissions.

5.1 INTRODUCTION

Long-term stabilization of the atmospheric concentrations of greenhouse gases will require sustained implementation of strategies that address four major areas of human activity: energy production and use, industry, agriculture, and the use of forests. This section discusses the array of technical options at our disposal for reducing the growth in greenhouse gas emissions and ultimately, making the transition to energy and economic systems in which the impact of human activities on the climate system is permanently limited to acceptable levels. The options focus on energy, forestry, and agriculture. A.I.D. is not presently involved in the phaseout of CFCs and related compounds, although the ultimate role of the Agency is under discussion.

5.2 ENERGY TECHNOLOGY OPTIONS

5.2.1 Introduction and Overview

The U.S. and the other OECD countries are likely to account for a declining share of future greenhouse gas emissions, while the rapidly industrializing developing regions will contribute a substantially greater share over the coming three to five decades. In virtually all developing countries the per capita commercial energy use is a small fraction of the per capita energy use in even the poorest European countries. Even with the most aggressive energy efficiency strategies in developing countries, total energy demand for fuels and electricity will continue to grow in these countries for many decades.

Controlling greenhouse gas emissions associated with energy use requires technologies that (1) improve energy conversion, transport, and end-use efficiency, (2) use carbon-free or less carbon-

intensive fuels, and (3) replace or reduce emissions of other greenhouse gases. Policies to reduce emissions must promote demand-side measures that increase efficiency, supply-side measures that encourage the development and use of fuels that are less carbon-intensive, and increased efficiency in fuel conversion.

Many technical changes that can slow the growth in greenhouse gas emissions appear feasible at reasonable economic costs, although the widespread diffusion of such technologies will require innovative institutional and financing initiatives throughout the developing world. No single technology can adequately control greenhouse gas emissions, but by aggregating the effects of many technical opportunities over the next 30-50 years significant reductions in greenhouse gas emissions can, in principle, be achieved. The time required to stabilize atmospheric concentrations of greenhouse gases and the levels at which these gases will stabilize will depend on the control policies and programs that are developed and the speed and scale of their implementation worldwide. These will also depend on the nature, rapidity, and extent of economic development, principally outside the OECD nations, over the next half century.

Global climate change is a long-term problem. Reducing and ultimately *stabilizing* the anthropogenic emissions of CO_2 and other greenhouse gases at acceptable levels may eventually require the very large-scale use [at the equivalent rate of perhaps 10-30 TW(th)] of advanced renewable and nuclear energy technologies for production of electricity and fuels. **Both renewable energy and nuclear energy systems appear to be more expensive currently than fossil fuel alternatives for most applications. However, using present energy and technology prices as a basis for assessing long-term technological and policy alternatives is misleading since neither the present environmental costs of fossil fuel pollution nor the future costs of climate change are reflected in present prices of goods and services.** The relative economics of alternative energy options will shift as the environmental costs and benefits of these options are internalized in their prices.

The importance of market incentives to improve technologies and reduce costs has been demonstrated in the recent experience with CFCs. Development of substitutes for CFCs has proceeded quickly once it became apparent that environmental regulation would require these substitutes; prior to the Montreal Protocol, industry was arguing that there were few feasible options at any price.

Many of the control options summarized here are economically justified today, or nearly so. This is especially true of measures to improve energy efficiency, where substantial opportunities for cost-saving investments remain. However, the appearance of economic competitiveness of these technologies with established practices can be misleading; many technically proven and seemingly economic technologies are often rejected for institutional and cultural reasons. Innovative programs, such as those discussed

in Chapters 6 and 7, will almost certainly be necessary to catalyze the introduction and widespread diffusion of both end-use and supply-side technologies that can address the twin goals of affordable, sustainable economic development and environmental harmony.[1]

5.2.2 Demand-Side Measures and Efficiency Improvements for the Near Term

According to a recent U.S. AID study,[2] while "industrialized countries have made major strides in using electricity more efficiently over the last decade, few achievements have been made in developing countries in using electricity more efficiently. The opportunities for improvements are tremendous, and the cost is only a fraction of the generation expansion option." **Improvements in end-use energy efficiency have the greatest potential for slowing the growth of CO_2 and other greenhouse gas emissions in the near term over the next few decades, both in the heavily industrialized regions and in the developing regions.**

In many developing countries there are distinct modern and traditional sectors. In the modern sector, energy-use patterns are very similar to those in industrial economies. Commercially marketed fossil fuels and electricity provide the energy input for a similar mix of energy services: space conditioning, water heating, lighting, and appliances for cooking, refrigeration, entertainment, etc. This modern sector, however, is often smaller than the traditional sector, which exhibits completely different energy-use patterns.

A major energy source in the traditional sector is biomass, used primarily for cooking and for space heating in some colder or high-altitude regions of developing countries. Kerosene is widely used for lighting. (In China, unlike most other developing countries, coal is also used for residential cooking and space heating in the traditional sector.) The task of development projects in these poorer sectors is to *vastly increase* the level of *energy services* available for residential and commercial applications. **The important issue from a climate perspective is to increase energy services without increasing greenhouse gas emissions.**

As the developing countries continue to increase their per capita energy production and use, the implications in terms of energy use and greenhouse gas emissions are enormous. Emissions-reducing strategies similar to those proposed for industrialized countries can be promoted in the modern sectors of the developing countries. Strategies suitable for the traditional, poorer sectors must be integrated into ongoing development programs if they are to be accepted by the local population. Technical options for reducing greenhouse gas emissions must not only be efficient, they must also be designed to increase energy services to these poorer sectors. Achievable efficiency improvements in the industrial (including agriculture), transportation, and residential and commercial sectors are discussed below.

Industrial Sector

Industrial end uses account for the largest single component of energy use in the industrialized countries -- almost 43% of the primary energy consumed in the OECD in 1985. In developing countries, if agriculture is included as part of industry, then the industrial sector generally consumes an even higher percentage of total commercial energy. **In developing countries as a whole, industrial energy makes up 50-60% of total modern energy use.**

In contrast to industrialized countries, developing countries are expanding energy- and material-intensive industries to raise per capita income levels. In addition, industries in these countries use energy far less efficiently than do similar industries in industrialized countries. In many cases this reflects energy price subsidies, lack of access to hard currency and to modern technologies, and lack of management skills for identifying and implementing efficiency options.

Technically proven cost-effective energy conservation techniques and processes can save developing countries an estimated 10-30% of industrial sector energy and 10-25% of power sector energy consumption. In Pakistan alone, $9.7 million worth of energy savings has been identified through a series of energy audits; $2.0 million has been captured to date. In Morocco, it has been estimated that the net present value of a full-fledged national energy demand management program through 1996 may exceed $150 million. In India, a 10% reduction in industrial energy use would result in $1 billion in annual savings. In the Philippines, the overall conservation potential is estimated to be $500 million per year.

Emission controls: Low-cost control technologies are available to reduce CO from automotive and industrial sources and NO_x from power plants. Other technologies are available that remove larger fractions of these pollutants but at higher costs. Emerging control technologies and combustion technologies with inherently lower NO_x emissions are being tested and could reduce NO_x emissions drastically at lower cost. In a few situations (i.e., enhanced oil recovery) CO_2 recovery from power plant flue gas may be economic.

Methane emissions from coal seams, natural gas production, and landfills can be reduced. Present minor emissions from coal production and landfills are projected to grow in the future. Natural gas is sometimes vented and often flared in conjunction with oil production. Technologies exist for economically recovering this methane and using it for energy production, thereby partially augmenting natural gas supply.

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Transportation Sector

To date A.I.D. has not initiated major programs dealing with transport. Yet transportation energy use is a serious concern in developing countries. **The largest component of the dramatic increases in oil use in developing countries during the last decade has been in the transportation sector.** Energy use for transportation has been growing rapidly in recent years in developing countries, and this high rate of growth is expected to continue in the future. From 1973 to 1986, oil use by developing countries increased by 60%. During this same period, oil used by OECD countries declined by 13%. Recent projections by the Department of Energy indicate that the overwhelming majority (80%) of growth in oil consumption in the "free world" through the year 2010 could come from developing countries.* For fifteen of the largest developing countries, about 50% of the growth in oil consumption in the 1970-1984 period has been in transportation.

The approaches that have slowed the growth of transportation energy use in the industrialized countries over the past 15 years may not be as effective in many developing countries. Industrialized countries have been able to significantly reduce the average consumption of fuel per highway mile by replacing existing vehicles with more efficient models and developing or expanding mass transit in urban areas. **The potential effectiveness of these approaches in most developing countries is much more limited because of the slower turnover of vehicles and lack of capital to invest in infrastructure improvements.** Automobiles with 50 mpg fuel efficiency are commercially available. Further improvements could increase fuel efficiency to more than 80 miles per gallon without compromising safety, comfort, or performance. Similarly, opportunities for implementing major fuel efficiency improvements in diesel trucks, rail transport, and aircraft have been identified.

Residential and Commercial Sectors

Between 1980 and 1987, electricity consumption in residential and commercial buildings significantly outpaced growth in total electricity consumption in many developing countries. It is expected that rapid expansion of the residential and commercial building stock will occur in conjunction with economic development in the developing countries over the coming decades. Use of the efficiency options currently available in industrialized countries, adapted to local conditions and objectives, could minimize the increases in energy use associated with this growth. Obviously, since the rate of construction of new building space (and distribution of appliances, etc.) will be much higher in developing countries, the importance and potential impact of efficiency measures will be proportionately greater as well.

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* The free world is defined by DOE to exclude the centrally planned economies of Eastern Europe, the Soviet Union, China, Cuba, Kampuchea, North Korea, Mongolia, and Vietnam.

Accelerated diffusion of improvements in building shells, lighting, space conditioning, and appliances could reduce energy consumption per square foot by 75% below current levels by 2025 for residences and at least 50% for commercial buildings. The residential energy efficiency goals are most likely to be achieved in the OECD countries; the goals for commercial buildings can be attained worldwide since large commercial buildings can utilize the same climate-sensitive design and technology control strategies worldwide.

Also, air conditioning requirements are generally heavier in tropical developing countries. Thus, improvements in building shells and air conditioning equipment could be very effective in reducing electricity use. Similarly, the air conditioning benefit (due to less waste heat) of improved lighting would also be greater in developing countries.

A recent study identified cost-effective efficiency improvements that could reduce commercial sector electricity use in Pakistan by over 30%.[2] Based on commercially available improvements in lighting, air conditioning and fans, and thermal insulation, the study projected national savings of 1,800 MW of generating capacity and 18,200 GWh/year of electricity consumption. An analysis in Brazil indicated there is *technical* potential to reduce electricity use for lighting by 60% in many commercial buildings.[3]

Several recent studies have identified significant potential for reductions in energy use in new commercial buildings in developing countries. Careful use of daylighting alone has the potential to reduce energy use by roughly 20% relative to the current building stock in Singapore.[4] Other important improvements include efficient lighting systems, external shading, and size and placement of windows.

However, in spite of all of these potentially attractive options, some of which are discussed below, *a major international effort to educate architects, engineers, and local building authorities,* and incentives to introduce the high-efficiency materials and products required to achieve high-efficiency buildings, will be required if any of this potential is to be realized. Experience in the U.S. and elsewhere in OECD has shown that **without the necessary legislative requirements for performance-based energy efficiency in commercial buildings, the necessary investments in efficient buildings, attractive as they may appear on paper, will simply not be made.** A.I.D. has supported a successful prototype educational and training program in recent years in the ASEAN region; far greater and more sustained efforts of this kind will be required to transfer the full technology of energy-efficient building design and operation to the developing world.

Lighting: Improved lighting techniques offer some of the most cost-effective opportunities for saving energy. Lighting accounts for about 20% of total U.S. electricity consumption, most of it in residential and commercial buildings. It can consume a similar fraction of electricity production in

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developing countries. In India, about 17% of total electricity consumed is for lighting, with as much as 35% of peak power generating capacity used for lighting. One study has estimated that 40 large (1,000 MW) power plants in the U.S. could be eliminated by implementing available, cost-effective lighting efficiency improvements.[5]

In the traditional sectors of developing countries, lighting involves very inefficient combustion technologies. In India some 80% of households use kerosene lamps. Providing the same level of illumination with incandescent electric bulbs would be 200 times more efficient at the end use.[6] Even if electricity production is only 30% efficient and is coal fired, the equivalent electric lighting would still produce less net CO_2. A recent study indicates that substitution of incandescent lamps by compact fluorescent lamps in India would save the equivalent of 6,000-10,000 MW of installed generating capacity.[7]

Appliances: After space conditioning and lighting, the remaining energy uses in residential and commercial building are for large appliances. Opportunities for significant efficiency improvements are well documented. U.S.-made refrigerators average 1,450 kWh per year, but the best currently commercial model in the U.S. uses only half that much. A recent study indicates that efficient new refrigerator/freezers that would consume less than one-sixth the electricity of current models could be economically produced.[8] Appliances could be produced in the 1990s that would be at least 50% more energy efficient than the 1986 average for all major energy-using residential appliances.[9]

5.2.3 Supply-Side Options for the Near Term

Near-term reductions in greenhouse gas emissions per kWh produced are possible through generation efficiency improvements and by switching from coal and oil to natural gas. Natural gas emits just over half the carbon per unit of combustion energy as coal. Improved fossil fuel electricity generation technology, such as advanced combustion turbines, combined cycle systems, and cogeneration, can increase fuel efficiency by 25 percent or more.

Clean Coal Technologies and Repowering

As new power plants are constructed to meet increasing electricity needs, many of these plants will be fossil fueled. The associated greenhouse gas emissions can be reduced by using the most efficient conversion technologies. These technologies significantly reduce emissions of traditional air pollutants such as sulfur dioxide and nitrogen dioxides. Some of these technologies improve fuel efficiency by 10-25% relative to conventional coal combustion technologies, hence reducing the associated CO_2 emissions.

Three of these advanced technologies currently in an advanced development phase are atmospheric fluidized bed combustion (AFBC), pressurized fluidized bed combustion (PFBC), and Integrated Gasification Combined Cycle (IGCC). AFBC power plants (essentially commercial now) are very similar in efficiency to conventional technology, and therefore minimally beneficial for reducing carbon dioxide emissions. PFBC and IGCC systems are projected to increase conversion efficiencies by as much as 10-20%, with corresponding reductions in CO_2 emissions per unit of electricity produced.

Clean coal technologies can be used for both newly constructed power plants and to "repower" existing power plants. In repowering, the combustion system is replaced with one of the new technologies. Other new components, such as a gas-fired combined cycle turbine, may also be installed. The result is a hybrid plant with performance very much like that of an efficient new unit.

Cogeneration

Cogeneration is the production of both steam and electricity from the same source, with the steam used to meet on-site heating and process requirements and the electricity used on-site or sold to electricity customers. Cogeneration has been very popular with large industrial energy users as one approach for reducing their overall energy costs. Most of the approximately 18 GW of currently operating cogeneration projects in the U.S. and an additional 29 GW under active development fall into this category.[10]

Advanced Gas-Fired Combustion Technologies

An option for increasing natural gas use is the construction of new gas-fired combined cycle or combustion turbine power plants. These power plants cost significantly less to build than coal power plants and are typically more energy efficient. They could also be part of a near-term solution since the lead times for plant siting and construction average about 2-4 years versus 6-10 years for coal-fired power plants.

Aeroderivative Combustion Turbines

Advances in jet engine turbine technology are being applied to turbines for generating electrical power. Present simple and combined cycle systems have efficiencies of about 32% and 42%. Conventional coal power plants have efficiencies of about 31-32%. Recent improvements in aeroderivative (jet engine) technology will significantly improve these efficiencies. The steam-injected gas turbine (STIG) has recently been commercialized. STIG units take steam not needed for process heat requirements and inject it back into the combustor for added power and efficiency. In a simple cycle application the efficiency of the turbine might be 33% with an output of 33 MW, while with full steam injection the efficiency would increase to 40% with an output of 51 MW.

With proposed improvements the single cycle efficiency would increase from 33% to 47% and the rated turbine output could be increased from 33 MW to 110 MW; the estimated capital cost of STIG is about $400/kW.[10]

Non-Carbon-Based Energy Sources

Non-carbon-based energy sources could make an important contribution to reducing greenhouse emissions in the medium term and could virtually eliminate many categories of emissions over the long term. In the long term, it appears that large-scale displacement of fossil fuels by non-fossil alternatives is necessary in order to achieve the stabilized greenhouse gas concentration levels. The relevant and difficult policy issue is whether or not it will be necessary to achieve this level of stabilization in order to limit climate change-induced problems to a generally acceptable level.

The principal non-fossil fuel primary energy options are discussed very briefly here; extensive information on these options is widely available elsewhere and will not be repeated in this report.[11]

Hydroelectric power. Already making a significant contribution to global energy production, hydroelectricity production in 1986 was 661 TWh in the developing world and 1,366 TWh in the industrialized world.[12] This corresponded to 413,000 MW in the industrialized countries and 154,000 MW in the developing countries. There is a major technical potential to expand this contribution. One World Bank scenario for future primary global energy use indicates the technical potential for increasing by fourfold the production of electricity from hydropower in the developing world. However, as the World Bank has carefully pointed out, environmental and social impacts of large-scale projects must be considered carefully, and these potential impacts will limit hydropower development in many developing regions.

Biomass energy. Advanced technologies for conversion of biomass to gaseous and liquid fuels and electricity, especially the use of gas turbines for power generation, combined with measures to increase biological productivity, would allow biomass to provide a much larger share of global energy services over the long term, particularly in developing countries. There is considerable discussion regarding the rates and scale of implementation of biomass-based energy and power generation systems.[13]

Geothermal energy resources are extensive and widely distributed. Over 7,000 MW of installed generating capacity are in operation worldwide. With improved technology, it may be possible to expand this energy source significantly in the future.

Wind energy systems for grid-connected power generation are commercial and competitive with some oil-based power generation, with over 1,500 MW of grid-connected wind electric power plants installed and operating in California. Recent engineering advances and production scale economies have resulted in reductions in cost and improvements in performance. As this trend continues, wind energy has the potential to play a significant role in future energy production in those countries with major wind energy resources. In the developing world, countries such as Egypt and India have the potential for several GW of grid-coupled wind electricity. Global estimates for the upper level of production of electricity from wind energy conversion are on the order of 1 TW.

Solar Thermal Electric Power Generation. Conversion of solar-generated heat to electricity has been established as a commercial reality in California, with several hundred MW of grid-connected solar power plants on line, and several hundred MW more coming on line by 1993. The commercial development of this option, as with wind technology, was made possible through a combination of Federal and California state tax credits, and the very attractive power purchase contracts implemented under PURPA regulations in California.[14]

While the costs of electricity production from solar thermal electric power systems are still higher (~$0.10/kWh) than for fossil-fuel power plants, this technology offers the potential for relatively near-competitive power generation within a decade or so, provided production scales can reach several hundred MW or more per year. A recent change in the provisions of PURPA eliminate the 80 MW limitation on privately owned renewable energy power plants in the United States, clearing the way for larger (~250 MW) solar power installations that are projected to have 20-30% lower capital and operating costs than the best present systems.

Photovoltaic Power Systems. In 1986 approximately 35 MW of photovoltaic (PV) power systems were produced and shipped as commercial products. Significant technological advances and rapidly increasing production have lowered the costs of electricity production from PV systems from several dollars per kWh to roughly $0.25-0.40 per kWh. In many parts of the developing world this is competitive with the *actual* costs of electricity from small diesel units. While the present applications of PV systems in the developing world focus on small-scale applications of electricity for water pumping, water purification, rural lighting, health clinics, and communications, widespread applications for irrigation and rural electrification are expected to begin this decade with further reductions in PV system price. Already India has equipped thousands of villages with PV lighting systems, and the goal of the Indian Government is to provide some degree of PV-based rural electrification in as many as 100,000 villages over the coming ten years.

Nuclear power from fission is a global technology, growing in its contribution to global energy supply due to the completion of power plants ordered during the 1970s. While nuclear power is often thought of as an option for advanced industrialized countries, it is extensively used in a number of developing countries and wider use in LDCs is expected over the coming several decades. In 1986 there were 2,700 MW of nuclear power generation on line in China, 1,200 MW in India, 1,300 MW in Mexico, 626 MW in Brazil, and 125 MW in Pakistan.

High capital costs and national and international concerns about safety, nuclear weapons proliferation, and radioactive waste management have brought new orders of nuclear power plants to a halt in most countries. It is technically feasible to expand the contribution of nuclear power on a global scale if these problems are resolved by commercializing a new generation of modular, inherently safer reactor technology and by developing socially and politically acceptable methods for radioactive waste management and control of proliferation. The U.S. and a number of OECD countries are actively working to develop a new generation of inherently safer reactors; the future social and political reactions to the availability of these options are not predictable.

Long-Term Use of Renewable Energy Technologies

The energy needs of modern societies are provided by electricity and high-quality liquid and gaseous fuels as the secondary energy carriers. The long-term *strategic roles* of both nuclear energy and renewable energy resources could be to provide electricity and chemical fuels on a scale of 10-30 TW(th). In principle this can be achieved through the use of nuclear and renewable energy sources to split water into hydrogen and oxygen, with the hydrogen used as the universal secondary energy carrier and energy storage medium.

A hydrogen economy based on a mix of renewable and nuclear primary energy sources would virtually eliminate civilization's energy-based emissions of greenhouse gases.[15,16] Such an energy system would permit long-term stabilization of the atmosphere with regard to greenhouse gases, and also bypass many of the local and regional air pollution impacts of fossil fuel use. Transition to an energy economy based on a hydrogen infrastructure would require over a century once the fundamental technological building blocks were available in commercial form and could be produced on a strategic scale.

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5.3 FOREST MANAGEMENT OPTIONS

5.3.1 Introduction

Since the turn of the century, more than half of the world's tropical forests has been lost. Recent FAO estimates* put the annual rate of deforestation during the decade of the 1980s at 17 million hectares, or approximately one percent of the 1990 stock. Perhaps more important is the fact that the rate of deforestation is accelerating. Moreover, deforestation is only the most obvious aspect of what is happening to the tropical forests. More insidious, and perhaps more important in the long term, is the degradation of land still classified as forested. No estimates are yet available, but the problem could be severe.

The causes of deforestation and forest degradation vary from place to place, making it difficult to make valid generalizations about how best to reverse or at least slow the trend. For the most part, the root causes lie outside the forestry sector itself, and have to do with rapid growth of economically marginal, rural populations, failure of markets to reflect the value of goods and services (productive and environmental) provided by forests, and policies that encourage -- or fail to discourage -- uneconomic, unsustainable conversion of forests to alternative uses.

5.3.2 Potential for Reducing Atmospheric CO_2 Concentrations via Forestry Initiatives

There is no consensus as yet on this issue. Some have pointed out that forestry offers an effective and relatively inexpensive means for sequestering large amounts of carbon. For instance, under one IPCC scenario tropical forests would absorb approximately 700 MMT of carbon per year by 2025, enough to offset more than one-half of U.S. fossil fuel emissions at current levels. Achieving this result would require halting tropical deforestation by that year, and reforesting or afforesting approximately 1 billion hectares by the year 2100. Because estimates of degraded tropical lands capable of growing trees range as high as 865 million hectares, some have concluded that a forestry initiative of this dimension is feasible and would be cost-effective.

At the other end of the spectrum, others have observed that the existence of vast expanses of degraded land does not necessarily mean that the land is unused and available for growing trees. Others have emphasized the difficulties of halting tropical deforestation in many tropical areas where fuelwood is in short supply and increasing population is likely to maintain, or even increase, pressure to convert currently forested land to agriculture. Yet others have noted the practical difficulties of large-scale afforestation programs in developing countries and point to relatively poor past experience with survival rates of tree seedlings, lack of trained manpower, etc.

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* See footnote, page 2-6.

Given that (1) tropical deforestation may account for as much as one-third of total global carbon dioxide emissions, and (2) potential biomass increase rates in the tropics are considerably higher than they are in temperate areas, there are significant reasons to include tropical forestry initiatives as important elements in an overall strategy for reducing net CO_2 emissions. **Nevertheless, because of the aforementioned uncertainties about the feasibility of achieving either a dramatic reduction in deforestation or a major increase in reforestation/afforestation activity, targets expressed in terms of quantities of carbon emissions reduced or CO_2 sequestered should be modest.**

These uncertainties, however, do not undermine the strong case for sound forestry initiatives. Whether or not their impacts on atmospheric carbon concentrations worldwide are as substantial as the more optimistic observers believe, **such initiatives can be amply justified on the basis of other benefits that accrue directly to the residents of the countries or regions in which they are undertaken -- protection of watersheds, soil stabilization, production of a host of wood and non-wood products, flood control, and preservation of habitat for plant and animal species (conservation of biodiversity).**

Tropical forestry initiatives required to achieve reductions in, or offsets to, carbon emissions from human activity will of necessity involve a range of activities focused much more on sustainable management of existing forests than on creating new ones (although afforestation efforts can also make a positive contribution). The elements of sensible approaches will vary widely from country to country, and perhaps within countries as well. A.I.D. experiences in developing countries point to the need for considering the following strategies:

Substitute More Stable, Sustainable Agricultural Practices

Swidden agricultural systems involving cutting and burning of tropical forests are widespread. Research suggests that substituting such sedentary practices as *agroforestry* -- in which crops or animals share plots of land with trees in production systems which are mutually beneficial -- could save 5-10 hectares of tropical forest for every hectare on which agroforestry practices are introduced. Potential carbon storage has been roughly estimated to range from 0.1-4.7 tons per hectare per year for different agroforestry systems exclusive of carbon stored in soil and carbon savings from avoided deforestation, both of which could be substantial. Since normal forest fallow may sequester more carbon than stable agroforestry practices, the latter may make its greatest contribution by reducing deforestation.

From a technical perspective, agroforestry looks promising, although research to date has been limited to a few techniques, species, and environments. Research priorities need to be informed by field experiences; this approach is currently being pursued by various aid donor agencies, including A.I.D. For example, at least in much of West Africa, increasing forestry biomass (as a means to sequester carbon)

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comes when smallholders change the way that they manage forestry resources; large, central schemes have been less successful.

In this context, constraints to adoption of new practices are as much non-technical as technical. Although many factors attributable to changes in management are site specific, we have found that several conditions have been relatively common and that wider diffusion is more likely under the following circumstances:

- resource users have use rights to products of better management;
- financial risks are acceptable (due to access to credit, markets, labor, etc.);
- cooperatives support enterprise;
- users have access to appropriate technologies; and
- users have observed practices and have access to technical knowledge.

It would follow that research should focus on the various policies, financial strategies, and institutional reforms that have contributed to smallholders managing forestry resources differently.

Increase Harvesting of Non-Timber Forest Products to Reduce Pressure for Forest Conversion

Nuts, medicines, fruits, oils, fodder, latex, bamboo and numerous other products are widely used in the forest areas in which they are produced, but frequently are undervalued, or not valued at all. This has put such uses at a comparative disadvantage with commercial timber harvesting which often receive explicit or implicit subsidies because they generate foreign exchange earnings. One response has been the establishment of "extractive reserves" -- forest areas reserved for harvesting of products on a sustainable basis. In Brazil, for instance, reserves have been established for harvesting of nuts and rubber. However, many questions must be answered before an estimate can be made of the potential of using such reserves as part of a global climate change strategy, e.g., costs, extent of markets for extracted products, and extent to which products can be harvested sustainably. Some private efforts are underway to increase local incomes to harvest and market these products. Additional efforts are required to further develop these approaches in a sustainable manner.

Use Natural Forest Management Techniques to Increase the Growth and Productivity of Existing Natural Forests and Plantations and to Sustain Natural Forests.

Natural Forest Management (NFM) techniques involve cutting to promote natural seeding and regeneration and to reduce damage to the remaining stand. They may be useful alternatives to prevalent tropical forest logging practices, which often damage many more trees than are actually harvested. While

NFM is a promising strategy for slowing deforestation and forest degradation, resolution of the problems associated with commercial logging also require attention to economic policy and institutional problems that militate against sustainable forestry in the tropics (e.g., logging concessions that are too short to encourage sustainable practices, explicit or implied subsidies, etc.). While there are no very reliable estimates of the potential for using NFM techniques to sequester carbon, it would be difficult to bring a significant portion of existing tropical forests under organized management schemes. Only a very small fraction of forests in the tropics are currently under management.

Again, as in agroforestry, West Africa has much to offer with respect to learning about diffusing natural forest management. Natural forest management has grown in Niger to cover from 5,000 ha in 1985 to over 200,000 in 1989 and the trend may continue, not only in Niger, but in other Sahelian countries. The lessons from the U.S.A.I.D.-sponsored Forest Land-Use Planning (FLUP) project need to be brought into focus. While technical improvements have contributed to the diffusion of the technology, other factors such as usufruct policy, credit, market, tax structure, training, extension, and cooperative development have been essential.

Besides management of forestlands, a growing number of Nigerian farmers have also pioneered natural regeneration of croplands with non-leguminous trees. This practice of maintaining field trees as sources of wood, forage, and soil fertility/conservation could contribute substantial quantities of biomass on land that is currently barren. The primary inputs are policy (localized changes in the forestry code) and extension (taking farmers to see model farms).

Reduce Conversion of Forests to Cattle Ranching

Although cattle ranching is generally not sustained on converted tropical forests for more than a few years, estimates of such conversions range from 3 to 7 million hectares a year, generally by burning. One study indicates that if the rate of conversions could be halved over a 25-year period, it would avoid release of 40-200 million tons of carbon a year to the atmosphere, a 2-7% reduction in carbon releases resulting from tropical deforestation at current estimated rates. While resistance to such a strategy should not be underestimated, Brazil's recent efforts to slow conversion of forests to pasture by removing incentives suggests that it holds promise.

Expand Use of Efficient Fuelwood and Charcoal Stoves

Fuelwood demand accounts for significant deforestation in some tropical areas, particularly semiarid, open forests. One study indicates that household biofuel cooking contributes 2-7% of total anthropogenic emissions of greenhouse gases.

In theory, more efficient cookstoves and industrial technologies could reduce wood requirements by 25-70% at very low cost. One study estimates that greenhouse gas emissions attributable to cookstoves could be halved. Another puts the reduction at 80 million tons of carbon per year, or 3% of greenhouse emissions from deforestation assuming that the stoves use 40% less fuelwood and that 175 million households use them. However, numerous past efforts to introduce improved stoves have not lived up to expectations, possibly because they did not save fuel or labor, or because wood could be gathered for free, and therefore was not highly valued, or because it was difficult to change present cooking practices. More efficient charcoal stoves have met with more success. The effect of their use is even greater when efficient charcoal production methods are used. Mass production and marketing of improved stoves to lower unit costs would also be useful.

Increase Reforestation and Afforestation Practices

These terms encompass replacing harvested forests with plantations and establishing forest cover on barren or denuded lands that may or may not have previously supported natural forests. Some authorities are enthusiastic about the prospects for large-scale reforestation and afforestation in tropical areas as a quick, cost-effective way to offset CO_2 emissions from fossil fuel use -- pointing out that growth rates in these areas exceed those for temperate and boreal forests and that the cost of establishing tropical plantations can be lower because of the low cost of labor and the availability of enormous expanses of degraded land.

Estimates of land available for reforestation and afforestation in the tropics are as high as 865 million hectares, enough to sequester over 3 billion metric tons of carbon a year, assuming an average carbon sequestration rate of 3.5 tons per hectare per year (a fairly conservative assumption). However, others have seriously questioned these estimates, pointing out that they grossly overestimate the availability of land for establishment of tropical forests. In some areas the conversion of forests to pasture has increased surface temperatures and decreased the soils water-holding capacity, making it more difficult to reestablish forests. Reforestation on a large-scale, worldwide effort is likely to be difficult and involve large investments. The cost-effectiveness of this approach should be compared to other means to reduce greenhouse gases, such as those discussed elsewhere in this report. However, it may be noted that reforestation can take place in unexpected places (as in farmers' fields). Again, decision-makers should not discount the potential of large numbers of smallholders to make a difference.

Social, economic, political, and ethical constraints to large-scale reforestation are even more important. Because of poverty and population pressures in many developing countries, degraded lands continue to be used (often further degrading them) and can be made available for long term investment in forests only if alternative livelihoods and living space can be found for those who depend on them. Absent such conditions, governmental institutions will likely prove inadequate to the task of ensuring that

the forests are established and managed over the long term to actually achieve carbon sequestration goals.

5.4 AGRICULTURAL MANAGEMENT OPTIONS*

Several specific actions can reduce greenhouse gas emissions from agriculture, although the magnitudes of the agricultural sources and the potential effects of control measures are difficult to quantify. Further research is required to produce credible estimates. Major agricultural activities of interest include the following:

- Methane emissions from livestock could be reduced by increasing the productivity of livestock systems and the use of methanogenesis inhibitors for beef cattle.
- Methane emissions from rice production may be reduced somewhat through productivity increases and removal of crop residues. In the long term, improvements in varieties of rice, soil amendments, and water management practices could decrease methane emissions.
- Biomass burning associated with agriculture produces N_2O, CO, and CH_4. Changes in agricultural practices -- sustainable agriculture, utilization of crop residues, etc. -- are technically feasible and could substantially reduce this source.
- N_2O emissions from fertilizer use could probably be reduced through better placement of fertilizer, nitrification inhibitors, and fertilizer coatings, which may also reduce farming costs and agricultural runoff problems.

Future agricultural practices and policies can affect the levels of greenhouse gas emissions from agricultural sources and contribute to stabilization of their atmospheric concentrations. However, reducing emissions from one or two sources will not be sufficient. For example, in order to stabilize methane concentrations, reductions in methane emissions from flooded rice fields, livestock systems, and biomass burning, as well as from other anthropogenic sources, will be necessary. Similarly, modifications in nitrogen fertilizer use, land-use conversion, and crop systems will be necessary parts of multisectoral strategies to achieve the reductions to stabilize atmospheric concentrations of carbon dioxide and nitrous oxide.

5.4.1 Near-Term Options

The opportunities for reducing greenhouse gas emissions in the nearer term, which appear to be economically viable in their own right, consist of the following:

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* The discussion in this section is drawn from the draft report of the IPCC Working Group III (Response Strategies) Subgroup on Agriculture, Forestry, and Other Human Activities. The IPCC discussion provides a framework for the A.I.D. initiatives in the agriculture sector.

- *Biomass burning*: Biomass burning might be reduced through fire control, education, and management programs, as well as through the introduction of appropriate alternative agricultural practices. Agricultural systems dependent on the removal of biomass by burning high-yield grain crops may be either modified to provide opportunities for increasing soil organic matter, thus reducing greenhouse gas emissions, or removed to provide use as an alternative fuel source.*

- *Livestock Systems*: Methane emissions can be reduced by managing livestock waste, expanding supplemental feeding practices for livestock, and increasing the use of production- and growth-enhancing agents with appropriate safeguards for human health and taking into account legitimate consumer concerns.

- *Fertilizer Use*: Nitrous oxide emissions may be reduced by using improved fertilizer formulations and application technologies, and through judicious use of animal manure.

- *Sustainable Agricultural Practices*: Where appropriate, minimum- or no-till systems are recommended for those countries currently using tillage as a part of the annual cropping sequence. Tillage systems may yield additional benefits such as direct energy savings, improved soil tilth and increase of soil organic matter.

- *Marginal Lands*: Areas marginally suitable for annual cropping systems should be shifted to perennial cover crops for fodder or pastoral land uses of woodlands, if soils are suitable. Such actions could increase carbon uptake, both in the vegetation and soil, and could yield other benefits such as reduced soil erosion, improved water infiltration and quality, and delayed stream flow.

5.4.2 Longer-Term Options Requiring Research and Demonstration

Several opportunities for reducing greenhouse gas emissions and enhancing carbon sinks have been identified for the longer term. In general, these opportunities must be developed, demonstrated, and assessed in terms of greenhouse gas reductions and the full range of potential costs and benefits. These alternatives must maintain or enhance the productivity of the agricultural systems. This will require substantial research efforts focused on better understanding of the processes by which these gases are emitted, further investigation of promising options, and better field measurement devices.

General longer-term opportunities for reducing emissions of greenhouse gases have been identified:

- A comprehensive approach, including management of water regimes, development of new cultivars, efficient use of fertilizers, and other management practices, could lead to a 10-30% reduction in methane emissions from flooded rice cultivation, although substantial research is necessary to develop and demonstrate these practices. A 10% reduction in emissions from rice systems

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* This latter option is actively being pursued by A.I.D.

might contribute about 15-20% of the total reduction required to stabilize atmospheric concentrations of methane.

- Through a number of technologies it appears that methane emissions from livestock systems may be reduced by up to 25-75% per unit of product in dairy and meat production. The net effect of such improvements depends upon the extent to which such methods can be applied to domestic ruminant populations, which will vary greatly from country to country. However, each 5% reduction from animal systems could contribute 6-8% toward the reduction necessary to stabilize methane in the atmosphere.

- Fertilizer-derived emissions of nitrous oxide potentially can be reduced (although to what extent is uncertain) through changes in practices such as using controlled-release fertilizers, improving fertilizer-use efficiency, and adopting alternative agriculture systems.

- Trace gas emissions from biomass burning, land conversion, and cropping systems may be reduced through widespread adoption of improved agricultural practices, optimal use of fertilizer and organic amendments, and improved pasture management and grazing systems. These gains may be offset by pressures of increasing population and increased demand for food and fiber production.

- In addition, policies associated with production, processing, storage, transportation, and marketing need to be examined to derive the optimum effectiveness from research, technological developments, and land use practices. Analyses are needed on economic incentives, taxes, pricing and trade barriers, cultural practices, technology transfer measures, education and information programs, and international financial assistance measures.

5.4.3 Greenhouse Gas Emissions from Flooded Rice Cultivation Sources

Flooded rice fields are a major source of methane emissions on a global scale, due to anaerobic decay of organic matter. While uncertainty exists as to the exact contribution of flooded rice fields to annual global methane emissions, it appears to be on the order of 25-170 MMT of CH_4 or 6-30% of annual global methane emissions. In addition, methane emissions from rice cultivation may increase by as much as 20% in the next decade, since rice production must increase to meet the rice requirements of growing human populations. Rice production is projected to increase from the current level of 458 million tons to over 550 million tons by the year 2000, and to some 760 million tons by the year 2020.

Measures and Policy Options

Reductions in methane emissions from flooded rice fields should be obtained while maintaining the productivity of the rice fields in all instances. In the long run, a comprehensive approach including management of water systems, cultivar development, efficient fertilizer (both organic and mineral) use, and other management practices could achieve reductions of 10-30%. However, current understanding of the complex interaction between methane production and oxidation, and the flux between the atmosphere

and the rice fields, is insufficient. Improving this understanding is a prerequisite for determining potential options for reducing methane emissions from flooded rice fields.

Improved understanding of the process contributing to methane emissions from flooded rice fields can only be achieved by integrated, interdisciplinary projects that focus on process-related factors and that will allow for valid extrapolation. Research is needed on the following aspects of this source of methane:

- the biogeochemistry of methanogenesis in flooded rice fields, including methane production, methane oxidation, and methanogenesis regulation factors;
- factors affecting methane fluxes from flooded rice fields, such as climate, soil and water, cultivars, fertilizer application, and cultural practices, and variations in fluxes spatially, seasonally, and diurnally;
- effects of techniques to reduce methane emissions of nitrous oxide; and
- field-level measurement techniques to assess spatial variability, and simulation models to synthesize the process and field level data.

Technologies and practices for reducing emissions from flooded rice fields need to be developed, demonstrated and assessed, and the costs and benefits evaluated. Furthermore, to realize the full potential of the research, existing and possible agricultural policies regarding rice production need to be examined.

5.4.4 The Role of Managed Livestock in the Global Methane Budget

Ruminant animals produce methane as part of the digestive process. Total methane emissions from the digestive process of all domestic ruminant animals has been estimated to be between 60 and 100 MMT of CH_4 per year, accounting for about 15% of global methane emissions, second only to flooded rice field systems. These estimates suffer from several notable uncertainties, which may cause overestimates of emissions in some areas and underestimates in others, resulting in an overall underestimation of methane emissions, possibly by large amounts.

In addition, animal wastes from all sources are another potentially large source of methane emissions. Under anaerobic waste management systems (animal wastes under aerobic conditions do not produce methane), uncontrolled methane emissions from cattle wastes are likely to be of the same magnitude as methane emissions from the livestock digestive process. Preliminary analyses indicate that emissions from this source may currently be on the order of 25-35 million tons of CH_4 globally, or about 30-40% of the methane from livestock digestive processes. Emission estimates from livestock systems

should be refined, particularly in areas where interventions and methane control are most likely to be cost effective.

Measures and Policy Options

Reducing emissions from livestock is a particularly attractive methane reduction option because it is usually accompanied by improved animal productivity. While there are considerable differences in feed conversion efficiency between extensively and intensively managed animals, several techniques are available that might reduce emissions per unit of product (e.g., per kilo of meat or liter of milk) by as much as 25-75%. Of course, the reductions actually achieved will depend on the extent to which and how effectively the appropriate technologies can be deployed. Furthermore, it is recognized that emissions reductions achievable with the best technologies, and the socioeconomic consequences of those reductions, will vary within and among countries with variations in animal, management, and feeding characteristics.

Near-Term Options

Several technologies are available in the near term:

- *Animal wastes.* Indications are that methane recovery through management of animal wastes can be economic in its own right under certain conditions.
- *Supplemental feeding practices.* Methane emissions can be substantially reduced (perhaps by 60%) from livestock on poor diets by strategic supplementation with locally-produced feed additives. Experience in India indicates that the supplementation system can be self-sustaining, economic investments.
- *Production-enhancing agents.* Current economic evaluations indicate that the use of bovine somatotropin (BST) could improve feed conversion efficiency and is economically feasible at this time, taking into account human concerns of the use of BST.

While currently available, these technologies and practices must be further developed, demonstrated, and assessed in terms of the full range of cost reductions, other potential benefits, and risks.

Longer-Term Options

Additional avenues exist for methane reduction in the longer term:

- *Strategic supplementation of extensively managed cattle.* Pastoral cattle management can result in relatively low animal productivity in some cases. Providing strategic supplementation of nutrients to these animals could reduce

methane emissions by increasing efficiency and productivity per animal and achieving production targets with smaller herds.

- *Diet modification for intensively managed animals.* Current research indicates that methane emissions vary under different diets. Increasing the food intake of animals and modifying the composition of their diet can reduce emissions per unit of product. Other feed inputs such as whole cotton seeds or polyunsaturated fats also appear to have promising impacts on methane emissions levels. Modifying feeding practices could potentially reduce methane emissions by large amounts in certain circumstances. However, the size and location of animal populations for which this is a promising alternative must be identified.

- *Reduction of protozoa.* Recent studies indicate that reduced protozoa in ruminant digestive systems results in lower methane emissions and may enhance animal productivity.

Further promising avenues consist of improvements in reproductive efficiency, which lead to smaller brood herd requirements, and microbiological approaches to improved digestion processes. Again, these technologies and practices must be further developed, demonstrated, and assessed in terms of costs, reductions, and other potential benefits. Also, techniques for field level measurements of methane from livestock need to be developed and standardized.

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CHAPTER 6

A.I.D. ONGOING INITIATIVES IN ENERGY, FORESTRY, AND AGRICULTURE THAT ADDRESS CONCERNS ABOUT GREENHOUSE GAS EMISSIONS

SUMMARY

A.I.D. is devoting increasing resources to forestry, agriculture, renewable energy, and energy efficiency projects and programs in over 40 developing countries, including most of those designated as "key" countries. A.I.D. energy initiatives include price reform, least cost planning in utilities, clean combustion technologies, use of renewables and alternate energy sources, and private sector power generation. Energy efficiency projects are being pursued in a number of countries, including "key" countries such as Brazil, India, Pakistan, and Philippines. Assessments of tropical forest and biological resources have been undertaken in 45 A.I.D.-assisted countries. Key forestry programs include regional projects that emphasize environment, natural resources and forest resource management and conservation and specific key country initiatives in Zaire, Mexico and Brazil. Innovative programs to reduce deforestation have been initiated. A.I.D.'s agricultural research, training and institutional strengthening, and policy programs directly or indirectly address climate issues. In FY 1989, the Agency provided $185 million in support of global warming activities, and planned funding in FY 1990 and FY 1991 are $225 million and $248 million, respectively.

6.1 INTRODUCTION

A.I.D. is supporting an array of activities in energy, forestry, and agriculture that, by their nature, address issues related to reducing greenhouse gas emissions. For example, the Agency has implemented energy programs that focus on increasing the technical and economic efficiency of the electric power sector in developing countries, and on reducing the local and regional environmental impacts of expanded power generation systems. A.I.D.'s growing forestry activities promote maintenance of forest resources and biological diversity, sustainable production from natural forests, management of wildlands, and management of critical watersheds.

A.I.D. is the largest and most active U.S. government agency in funding activities in developing countries to address climate change.* In addition to substantial independent climate change efforts, A.I.D. collaborates with the Environmental Protection Agency, the Departments of Agriculture, Energy, and Interior, and the National Science Foundation, as well as with non-governmental organizations. A.I.D. will

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* Many of A.I.D.'s activities in energy, forestry, agriculture, etc., as well as in training, institution building, and disaster assistance, have components which increase developing country capabilities to reduce greenhouse gas emissions and to deal with the potential impacts of climate change. A fuller description of these activities is in preparation.

forge additional linkages and pursue closer coordination as the pace of research and operational activities gathers momentum.

The A.I.D. climate change strategy will address specific concerns regarding both the causes and the consequences of the greenhouse effect and its impact on potential global climate change. It forms an integral part of the broader Agency program of environmental initiatives. Although concerns about global climate change are new to A.I.D., our active support for projects in the two areas of greatest relevance -- energy and forestry -- extends over many years. Based on our experience with many successful interventions, and our comparative advantage in these areas, energy- and forestry-related efforts are expected to comprise the core of our climate change program in future years.

A.I.D.'s approach to climate change is to support those initiatives that make development sense regardless of whether the initiative considers climate change specifically. Thus, investments will be made in energy efficiency or sustainable management of forest resources that protect important watershed areas only when such programs can be defended as economically and financially sound. This approach is the so-called "no-regrets" strategy for addressing the risk of global warming.

A.I.D. defines global warming activities as all projects and programs related to forestry, renewable energy, and energy efficiency. Within these categories, particular attention will be given to training and upgrading the skills of senior host country officials in the energy, forestry, and economics/finance/planning/policy fields and in providing support for their participation in international workshops and conferences organized around global climate change themes.

In FY 1989, the Agency provided $185 million in support of global warming activities, and planned funding in FY 1990 and FY 1991 is $225 million and $248 million, respectively. Our present level of assistance supports global warming projects or components of projects in approximately 40 bilateral missions as well as in additional countries through regional or centrally funded programs.

To achieve greater impact will require maintaining these increases in future levels of assistance, as well as a clear redirection of climate change resources. A large share of current resources -- more than 60% -- is directed toward nations that are not "key countries" under any definition.

6.2 A.I.D. ENERGY ACTIVITIES AND CLIMATE CHANGE

6.2.1 Introduction

A.I.D. is devoting increasing resources to the improvement of the energy sector in developing nations, including most of those designated as "key" countries. The Agency implements its programs

through its missions in A.I.D.- assisted countries, through its regional bureaus, and through its Office of Energy in the Bureau of Science and Technology. Key countries in which relevant energy programs are underway include Brazil, India, Pakistan, the Philippines, and Costa Rica (included in the Central America "key country"). There are important energy programs in other A.I.D.-assisted countries not designated as "key countries" but of major importance in the Agency's overall development program; these include the Dominican Republic, Egypt, Jordan, Thailand, and Morocco.

The Agency supports a multi-dimensional approach toward helping developing countries to improve technical, economic, and institutional performance in the energy/electric power sector. These programs include supply-side technology innovation (e.g., advanced coal combustion technologies, renewable energy systems), improved transmission and distribution, and an array of energy and electricity end-use efficiency measures in the industrial, commercial, agricultural, and residential sectors. In many of these countries there is an important component that focuses on energy pricing and price reform, least-cost planning, development of private-sector energy initiatives, and environmental management of the energy sector. The Agency considers many of these country-specific programs to be pilot programs that can be implemented in other A.I.D.-assisted countries over the next few years as experience is gained.

In collaboration with the multilateral development banks and other bilateral donor assistance agencies, the Agency also supports a number of initiatives that address issues of concern in virtually all developing countries. For example, for one program, being carried out jointly with the World Bank and several other bilateral assistance agencies, we are assessing the performance of electric utilities in over 20 countries; in another, we are working with other multilateral and bilateral agencies to develop an environmental guidebook for the electric power sector. The Office of Energy is working with multilateral and bilateral donors and A.I.D.'s Regional Economic Development Support Office for West and Central Africa in organizing a workshop on power sector efficiency for sub-Saharan countries, which is scheduled for the fall of 1990. The Agency is supporting a number of efforts that address pricing, private sector participation, least-cost planning, and other policy issues. Some of these collaborative efforts are described below.

Price Reform

Many LDCs heavily subsidize electricity prices, reducing the incentive to use energy efficiently. A.I.D. is promoting price reform in an effort to rationalize energy pricing policies. A.I.D. will publish a guide on successful price reform experiences and provide technical assistance and training on energy pricing policy.

The Bureau for Asia, the Near East, and Europe (ANE Bureau) is supporting the rationalization of power tariffs for rural customers through rural electrification projects in the Philippines, Bangladesh, and Pakistan. Also, placing conditions on energy sector grants in Egypt has resulted in a plan for reducing subsidies in that country's power sector.

Private Sector Participation

Lack of adequate capital and poor performance by public utilities is forcing many governments to adopt policy changes that will attract the private sector into power generation. A.I.D. has supported this major reform with a $170 million program in Pakistan in collaboration with the World Bank. In addition, the ANE Bureau Private Sector Power Initiative, in collaboration with the S&T Bureau Office of Energy, has supported assessments, workshops, and technical assistance programs in India, Thailand, Indonesia, and the Philippines. Expanded activities are planned to promote the competitive, efficient private-sector development of renewable and least-cost generation opportunities.

The Private Sector Energy Development Program (PSED) was established by the Office of Energy in 1989 to assist the private sector in solving the power shortage problem in developing countries. The PSED program provides a wide range of technical assistance, information dissemination, and project development activities to governments, utilities, and the private sector in support of private power/energy. Some of its recent activities include providing technical assistance to Indonesia and Guatemala for establishing rules, regulations, and avoided-cost methodologies; providing funds for private power feasibility studies in the Dominican Republic, Pakistan, Poland, and Turkey; and coordinating with the World Bank, U.S. Trade and Development Program, and the U.S. Department of Energy in conducting seminars and conferences.

Least-Cost Planning

Traditional utility investment planning assumes certain rates of growth in demand and focuses only on supply expansion. The Office of Energy is developing a comprehensive approach to least-cost investment planning that includes a review of economical ways of increasing efficiencies in generation, distribution, and end-use. The first applications of this approach are being pursued with the national utility in Costa Rica and with the State Electricity Boards of Maharashtra and Gujarat and the Department of Power of the Government of India (the latter effort is in collaboration with the World Bank).

Multi-Agency Working Group on Power Sector Innovation (MAGPI)

A.I.D. is expanding its collaboration with other bilateral and multilateral donors and lenders to assist developing countries in establishing innovative approaches to expand and upgrade the electric power sector. To facilitate this collaboration, the Office of Energy has established the Multi-Agency

Working Group on Power Sector Innovation (MAGPI), together with the World Bank, the Inter-American Development Bank, the Asian Development Bank, the African Development Bank, the International Finance Corporation, and the United Nations. The MAGPI is made up of about 15 senior decision-makers with operational responsibilities.

A.I.D. works closely within the MAGPI framework to identify and develop practical and bankable projects designed to catalyze innovation in the LDC electric power sector. In many of these activities, a technical and financial partnership with R&D institutions and commercial organizations in the industrialized countries will be required to catalyze bankable projects leading to the successful introduction and diffusion of the needed technological capabilities.

Managerial Improvement

Also under the collaborative umbrella of MAGPI, A.I.D. is working with the World Bank, the United Nations Development Programme, and several bilateral aid agencies to implement the Electric Power Utility Efficiency Study. The project sends teams to LDCs to determine the potential management, technical, and institutional improvements that can be made to isolated diesel power plants to improve performance. Studies have been completed in Indonesia, the Philippines, Guatemala, and a dozen African countries.

Training

To support these efforts, increased resources are being devoted to the training of host country officials and experts on energy planning, renewable energy systems, environmental management in the energy sector, energy efficiency, financing, etc. Training opportunities include formal course work, internships with U.S. energy organizations, and visits to U.S. energy facilities, including utilities, manufacturers, architect-engineers and private developers.

High-Efficiency Clean Combustion Technologies

The ANE Bureau, the Office of Energy, and the World Bank have initiated a project to accelerate the use of more efficient and environmentally clean combined cycle technology (using both steam and gas turbines to generate electricity). A technical report is being prepared in Egypt and Pakistan on gas turbine and combined cycle technologies that will be used as models for application in other developing countries.

Energy Efficiency in the Built Environment

The ANE Bureau funded the 3-year, $5 million ASEAN "Energy Conservation and Management" project, which focuses on energy conservation in buildings and includes a training component in energy management.

Energy and Transport

The ANE Bureau and the Office of Energy are cooperating with the U.S. Environmental Protection Agency and a Washington-based NGO, the International Institute for Energy Conservation (IIEC), in funding preparations for a regional conference on efficiency in the transport sector in Asia.

Renewable Energy and Alternate Energy Sources

A.I.D. has been involved in over 200 renewable energy programs in Asia, Africa, Latin America, and the Caribbean. These projects were intended to lead to a reduction in oil imports, augment domestic fuelwood resources, and increase energy self-reliance in developing countries, including A.I.D.-designated key countries such as India, Indonesia, Pakistan, the Philippines, Zaire, and the Central American region. These projects have involved the development and testing of solar, wind, biomass, biogas, and small hydro systems for meeting rural and village energy needs. Following a reassessment of A.I.D.'s Renewable Energy activities in 1987, its new thrust in this area emphasizes private-sector development and assistance programs to stimulate market-driven applications of renewable energy sources in developing countries.

6.2.2 Country-Specific Energy Sector Programs

Brazil

In Brazil, a key country, A.I.D. is working in coordination with other donor agencies to create an institute, to be operated by a non-governmental organization (NGO), that will work to increase awareness and implementation of energy efficiency in the private sector and provide policy advice to the government.

Central America

In Central America a $24 million energy planning project, funded by the regional office for Central America and Panama, has been assessing geothermal resources for electricity generation.

Costa Rica

Beginning in January 1990, A.I.D. began reviewing the status of the efficiency of the power sector in Costa Rica, another key country, and the end use of electricity in all concerned sectors. The objective of this project is to demonstrate that "least-cost planning" can be a useful tool to developing countries in

their efforts to increase energy efficiency. In the case of Costa Rica, it is expected that a full-blown least-cost plan could reduce the new capital requirements of the currently contemplated electricity generation plan by 25% between 1990 and 2000. Preliminary results of the field work, which took place between January and June 1990, will be available by Fall 1990.

The Agency is also supporting an innovative program to make use of agricultural residues in the sugar industry to fuel on-site private power generation. Part of an 11-year, $12 million R&D and project development program that focuses on power generation from biomass, the activities in Costa Rica have led to pricing reform, the development of an interim government decree permitting private power hookups and power sales to the national grid, as well as development of new privately owned biomass-fired power generation units. The Agency is working closely with the Inter-American Development Bank in the development of minihydro resources in the country. The Agency is also cooperating with the U.S. wind technology industry and the Costa Rica electric utility in assessing the potential for commercial grid-connected wind farms.

Dominican Republic

In the Dominican Republic, another key country, a component of the Mission's "Energy Conservation and Resource Development" project has been working with the industrial sector to establish a capability to perform energy audits and implement appropriate conservation measures. A.I.D. is working with the government to help develop legislation that will support private power initiatives and create incentives for more efficient operation of the electric power sector.

Egypt

Started in February 1989 and sponsored by the Government of Egypt and A.I.D., the $50 million Egypt Energy Conservation and Efficiency Project (ECEP) is intended to improve the productivity and competitiveness of the Egyptian industry by improving the energy efficiency of its commercial processes and practices in the public and private sector. The project will include demonstrations of conservation technologies, training, marketing and promotion, and policy studies. As of June 1990, an energy management system for an Egyptian hotel had been purchased; a cogeneration technical assistance and training course was held that included a familiarization tour of U.S. cogeneration facilities for the Egyptian directors of the public and private agencies involved in ECEP; and feasibility studies for combustion efficiency improvement projects and cement and glass industry energy surveys were completed.

Also in Egypt, A.I.D. has been assisting the Egyptian Office for Energy Planning (OEP) with a major energy policy and planning project that includes two rounds of in-depth energy audits in the agro, chemical, cement, and petroleum industries; these were conducted between 1987 and 1989. The

purposes of these audits were to identify the energy conservation opportunities at the plants, calculate the economic cost/benefits for the conservation measures, identify energy conservation-related policies that OEP should pursue, and train OEP staff in energy auditing. The reports have been presented to each plant management and the recommendations of the reports are now under consideration or being implemented.

The Renewable Energy Field Testing (REFT) project, a $25 million 8-year program is ending early in 1991. The program concentrated on U.S./Egyptian ventures in establishing test and demonstration facilities for wind energy conversion for power generation and solar thermal applications to industry. A recently completed A.I.D.-supported study has indicated major wind resources in Egypt and the U.S. wind industry is exploring the potential for grid-connected wind farms along the Red Sea.

India

In India, another A.I.D.-designated key country, A.I.D. is involved in efforts to improve the efficiency and productivity of the power supply and end-use sectors. The on-going $20 million PACER (Program for the Acceleration of Commercial Energy Research) project promotes development of goal-oriented and market-responsive technological innovation in the energy sector through financial assistance to consortia of manufacturers, research institutions, and end-users. Over 14 PACER projects in energy efficiency, renewables, and environmentally sound power technologies are at various stages of implementation. The $0.5 million Energy Efficiency component of the Alternative Energy Resources Development Project supported collaborations in the conduct of several workshops and two U.S. study missions by Indian private sector in industrial energy efficiency and cogeneration.

The $15-20 million EMCAT (Energy Management, Consultation, and Training) project, currently at an advanced design stage, will focus on policy, financing, and management innovations that aim to increase productivity of energy supply and end use. EMCAT represents a unique collaboration between key development financing institutions in the Indian electric power and industrial sectors, A.I.D., the World Bank, the Asian Development Bank, and other bilaterals. A.I.D. grant funds are expected to leverage substantial multilateral development bank funds and will permit technical assistance and training in supply and end-use energy efficiency loan portfolio designs, environmental assessments of power development projects, pre-feasibility studies of major energy efficiency and cogeneration projects, and the establishment of energy service companies in the private sector.

On the supply side, A.I.D. is assisting the Government of India in assessing the technical and economic feasibility of Integrated Gasification Combined Cycle (IGCC) technology as an alternative to conventional pulverized coal (PC) power generation technology. IGCC has the dual advantages of much higher energy efficiency (about 10-15% greater than PC) and virtually no emissions of particulates or sulfur

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dioxide. Efforts are underway to strengthen Indian technological capabilities in addressing the problem of combustion of high-ash Indian coals through innovative systems such as Atmospheric Fluidized Bed Combustion (AFBC) and slagging combustors.

A.I.D., together with the World Bank, is designing a comprehensive program to assess the long-term issues in the Indian power sector, including policy issues related to energy pricing, environmental impacts of power development, and investment planning. The goal of this program is to identify institutional, technical, and economic measures needed to address the relatively poor financial and technical performance of India's rapidly growing electric power sector.

Jordan

Beginning in November 1989, A.I.D.'s Office of Energy, in conjunction with the Government of Jordan's Industrial Energy Department of the Ministry of Energy and Mineral Resources (IED/MEMR), has begun an industrial energy efficiency program. This program has five project components: 1) assessing the local energy conservation capability, 2) conducting management and technical training, 3) conducting promotional activities, 4) providing technical assistance, and 5) studying incentives and regulations.

As of June 1990, $15,000 worth of energy audit instruments were purchased and shipped to Amman; an energy conservation training manual for industrial plant managers was developed; a 10-day training course on the principles of energy conservation was presented; technical brochures on energy conservation in boilers and steam systems were printed; three technical studies in Jordanian industrial establishments are being conducted; and terms of reference for six energy conservation policy studies were prepared.

Morocco

Starting in May 1989, A.I.D. began a $5 million, 5-year program designed to develop, manage, direct, and implement the Energy Demand Management (EDM) program for the country of Morocco. EDM will focus on three key sectors: agro-industry, construction materials, and hotels. EDM will provide these sectors with technical assistance, commodities, policy and technical studies, as well as training on energy demand management issues designed to develop and implement the core of a national energy management program for reducing energy waste and improving the efficiency of energy use.

As of June 1990, four cost-shared contracts for energy management services were signed with private clients, each contributing between MDH30,000 to 50,000 (approximately $3,750 - $6,250) towards audit costs. Three of these audits were successfully completed in food industries by the end of March,

and a cement plant has been targeted as the possible fifth cost-shared audit. In addition, a three-week training program on energy auditing was implemented.

Pakistan

Since 1986, A.I.D. has been involved in a 4½-year project to assist another one of its key countries, the Government of Pakistan (GOP), in developing and implementing a National Energy Conservation Program by providing technical assistance to the newly-created National Energy Conservation Centre (ENERCON). This technical assistance effort is aimed at improving the efficiency of energy use in all sectors of the economy (e.g., agriculture, industry, transportation, power generation, buildings) and to alleviate some of the serious threats that energy shortages pose to Pakistan's continued economic development.

In a little over four years, ENERCON has made impressive gains in saving the nation both energy and money. Over Rs 55 million (approximately $2.5 million) are being saved annually in factories and buildings. In addition, Rs 131 million (approximately $6 million) more in savings have been identified as a result of energy audits and are in the process of being implemented.

Other specific achievements of ENERCON include preparing a National Energy Conservation Law that was approved by the Pakistani cabinet; preparing a National Building Energy Code; implementing what may be currently the largest building energy conservation research project in the world; and conducting detailed energy audits of 42 industrial plants (identifying average energy savings of 22% per plant). Other activities included tuning up 366 industrial boilers and furnaces for an average 6% improvement in efficiency; tuning up over 300 automobiles for an average reduction in fuel usage of 11% (an unexpected bonus was an average reduction of hydrocarbons by 42%, and carbon monoxide reduction of 59%); retrofitting of 12 tubewells (agricultural pumps) for an average 66% improvement in efficiency; and training approximately 200 engineers in energy management.

The Energy Planning and Development Project ($105 million) started in 1983 has considerably strengthened GOP's capability to examine options that aim at expanding the energy resource base, energy efficiency and resource conservation. The Rural Electrification (RE) project ($250 million) has assisted the GOP in strengthening organizational and management capabilities of rural supply systems and in providing reliable and efficient electricity services. Specifically, the project has initiated a major energy loss and power transmission/distribution network rehabilitation program at the Water and Power Development Authority (WAPDA), GOP. In addition, as of May 1989, the RE project has provided in-country training for over 30,000 technical personnel on efficient power distribution. A private sector power project, initiated in late 1988 and funded at over $170 million, has been making rapid progress in

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mobilizing private-sector resources to build, own, and operate power plants. Under review currently is a $979 million oil-fired 1200 MW "Hab River Project."

Philippines

In the Philippines, another key country, the A.I.D. Mission is carrying out the "Technology Transfer for Energy Management" program, a 5-year, $5 million project begun in 1986. The project's goal is to accelerate the adoption of energy conservation technologies by consumers, especially those in the industry and commercial buildings sectors. The project includes demonstrations of commercially available technologies, studies, training, information dissemination, and assistance in establishing financing mechanisms.

6.3 A.I.D. FORESTRY ACTIVITIES AND CLIMATE CHANGE

Sections 118 and 119 of the Foreign Assistance Act of 1961, as amended, require A.I.D. missions to include in their country or regional development strategy an assessment of tropical forest and biological resources in that country (or region), and an analysis of required conservation measures. By the end of 1989, more than 45 A.I.D. country missions and sub-regional field offices were working on, or had completed these assessments -- 19 in Latin America and the Caribbean region (i.e., all A.I.D. offices in developing and advanced developing countries), and 13 each in Africa and the Asia and Near East region.

A.I.D. support for forestry activities is growing rapidly. In FY 1988 $50.2 million was obligated for 90 active projects. By the following year, A.I.D.'s portfolio included 112 projects, and obligations had increased to $76.8 million, a 53% growth rate. Moreover, as of the end of that fiscal year (September 30, 1989), an additional 23 tropical forestry projects were in the planning stage.

A.I.D. is expanding it forestry activities in all regions. Projects are described below, by region.

6.3.1 Latin America and the Caribbean

In Latin America and the Caribbean (LAC), every A.I.D. mission has now included tropical forestry and biological diversity sections in its country development strategy statement and action plan. In FY 1989, the LAC Bureau issued a document entitled "Environmental and Natural Resource Management in Central America: A Strategy for A.I.D. Assistance." This new strategy emphasizes sustainable agriculture, production from natural forests, management of wildlands to protect biological diversity, management of critical watersheds, as well as policy formulation, institutional strengthening, and environmental education. To address the issues identified in the strategy, a 10-year, $46 million Regional Natural Resources

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Management Project was initiated in late FY 1989. This regional project will support A.I.D. efforts in individual Central American countries currently estimated at over $300 million during the next 5 years.

The Development Strategies for Fragile Lands (DESFIL) Project, jointly managed by A.I.D.'s Science and Technology and LAC Bureaus, is designed to improve national, regional, and international strategies for fragile lands management in Latin America and the Caribbean. Recent activities conducted under this project include preparation of a natural resource management strategy for El Salvador and development of Tropical Forest Action Plans in a number of countries.

6.3.2 Africa

The Africa Bureau's Plan for Supporting Natural Resources Management in sub-Saharan Africa establishes natural resources as a bureau priority and provides essential technical and programming direction to the field missions. The Plan focuses on three priorities, tropical forest biological diversity, vegetation loss, and soil fertility decline, in three agro-ecological areas: (1) arid/semi-arid regions of Africa, (2) tropical highlands, and (3) Madagascar and other Indian Ocean Islands. A recent study supported by A.I.D. analyzed current and future carbon emissions from land-use change and energy consumption in sub-Saharan Africa.[1] The study concluded that three countries (Ivory Coast, Zaire, and Nigeria) alone contribute over 50% of 1985 carbon emissions from land-use change in sub-Saharan Africa.

In 1987, A.I.D.'s Bureau for Africa adopted the Plan for Natural Resource Management (PNRM) and initiated the Plan by funding a $14.6 million Natural Resources Management Support project (NRMS) to assist African governments in developing better approaches to managing their natural resources. Under the PNRM, funding has been increased annually from $52 million in FY 1989 to an estimated $80 million in FY 1991. Several important natural resource management projects and programs, which focus on the FAA amendments 118 and 119 (Tropical Forestry and Biological Diversity), have been initiated by the Africa Bureau in its Group I and II countries. These include such natural resource management activities as the following:

- development of an Environment Management and Protection Project for Madagascar as a major component of the World Bank-coordinated Environmental Action Plan,
- coordination and sponsorship of a regional workshop on afromontane forest management in Rwanda,
- development of nature tourism in Rwanda,
- development of a forestry land-use planning project in Niger,
- smallholder edification on tree, soil, and water conservation in Mali, and

- promotion of alley-cropping research to diminish the effects of slash-and-burn agriculture practiced in many developing countries.

To date, NRMS assessments are planned or have been completed in 16 of the 23 Category I countries (Cameroon, Ghana, Tanzania, Guinea, Kenya, Madagascar, Malawi, Mali, Senegal, Uganda, Botswana, Burundi, Gambia, Niger, Rwanda, and Zaire). Besides centralized funding of activities under the NRMS project, a number of Missions are contributing to wider diffusion of forestry resources management by smallholders:

- Several efforts have assisted Niger:
  - The Majjia Valley Windbreak Project has helped to protect 5,000 hectares of cropland from soil erosion. Besides reducing damage by wind and water, these windbreaks are harvested on a 4-year rotation; consequently, they are often on the rapid portion of the growth curve. Windbreaks are being diffused to other sites.
  - The FLUP Project supported the development of two model management sites that contributed to the extension of natural forest management to over 200,000 hectares in Niger. Actions in other Sahelian countries is increasing this number.
  - The Agricultural Sector Development Grant (ASDG) will be providing assistance to local communities to manage forestry resources.
- The Village Reforestation Project in Mali has assisted a number of smallholders in establishing pole plantations and living hedges. Under a new phase, the project is supporting studies that will lead to establishment of policy incentives to increase the numbers of field trees.
- Grants from a reforestation project in Senegal are used to share the cost of establishing field trees with smallholders.

In conjunction with other international donors, forestry sector reviews in preparation for Tropical Forestry Action Plans have been conducted in the following 11 Category I African countries: Cameroon, Ghana, Guinea, Kenya, Lesotho, Madagascar, Mali, Rwanda, Senegal, Togo, Zaire.

6.3.3 Asia and the Near East

A.I.D.'s Bureau for Asia and the Near East (ANE) has given priority to gathering the information needed to learn what actions are necessary in each country to achieve sustainable management of tropical forests and to conserve biological diversity. Background assessments have been completed for Morocco, Tunisia, Egypt, Nepal, Sri Lanka, Thailand, Bangladesh, the Philippines, Yemen, and Indonesia, and assessments are underway in Jordan, India, and the 10 nations of the South Pacific. Countries that will be covered next year include Pakistan and Oman. In some instances, the process is sufficiently

advanced to permit major activities to go forward. In Thailand, for instance, a $44 million Management of Natural Resources Project is underway. Major Forestry Development Projects are in progress in Pakistan, Nepal, and India, and new natural resources projects are planned to begin in 1990 and 1991 in Morocco, Sri Lanka, the Philippines, Indonesia, and the South Pacific.

Recognizing the need to place still greater emphasis on environmental and natural resource management, the ANE Bureau is preparing a regional program strategy that strongly supports conservation and management of tropical forests and biological diversity in the region. The strategy is designed to promote the following: (1) reform of development policies that take full account of environmental costs; (2) upgrading of environmental and natural resource management capabilities; (3) strengthening of technical and managerial aptitudes of the private sector; and (4) increased participation by NGOs, private organizations, and the public in resource development decisions. A multi-million-dollar Regional Environmental Activities Project will provide core funding for strategy implementation. Innovative ways of collaborating with other donors are being examined as a means of further support.

6.3.4 Agency Coordination

To manage its growing program and to leverage efforts by others, A.I.D. is working closely with an increasing number of private voluntary and non-governmental organizations, both in the United States and abroad. The Agency also collaborates with the Peace Corps, the Department of Agriculture's Forest Service, the U.S. Environmental Protection Agency (EPA), international institutions (including the World Bank, the Food and Agriculture Organization, the U.N. World Food Programme, the International Council for Research in Agroforestry, the International Food Policy Research Institute, the International Union of Forestry Research Organizations, the Consultative Group on Biological Diversity, and the International Institute for Tropical Agriculture), universities here and overseas, and the private sector.

6.3.5 Centrally-Supported Programs

Several projects managed from A.I.D.'s headquarters in Washington, D.C., provide technical leadership and assistance to A.I.D. field missions in the area of natural resources management, including management of forest resources:

- The *Forest Resources Management Project*, with a present staff of 10 full-time professional foresters, provides technical consultation to A.I.D.'s bureaus and overseas missions, research support, forestry training and forestry program studies, and technical reference services. Additionally, it manages a roster of 2,500 expert consultants in forestry and natural resources, maintains the principal database for A.I.D.'s forestry activities, and provides technical support for forestry and natural resource management programs of the Peace Corps.

- *A $40 million Forestry/Fuelwood Research and Development Project (F/FRED)* supports collaborative research networks in Asia and Africa with the International Council for Research in Agroforestry. The effort is aimed at developing and improving multipurpose tree species and encouraging their socio-economic acceptance.

- The *Environmental Planning and Management Project* is designed to strengthen the capabilities of developing country institutions to manage their natural resources for sustainable development.

- The *Conservation of Biological Diversity Project* provides technical assistance to help define conservation priorities, prepare national and local conservation strategies, and design activities. A small grants program is also being set up to support research on such questions as the effectiveness of buffer zones in insuring the integrity of protected areas, and the economic cost-benefit analysis of conservation investments.

- The *Environmental and Natural Resources Policy and Training Project*, now in the design stage, will provide research, policy development, institutional strengthening, and training services focusing on the effects of economic policy on the environment and natural resources, and the potential for using policy instruments to address deforestation and other environmental problems. It should be noted that "key" countries, as that term is defined in Congress' "global warming initiative" (Section 534(a) of the Foreign Assistance Appropriations Act of FY 1990), will be eligible for assistance under this project.

6.3.6 Innovative Programs to Reduce Deforestation

A.I.D. staff resources and funds, both from Washington and from projects managed at field missions, are being used for several innovative initiatives worthy of mention:

- A.I.D., in collaboration with EPA, has commissioned the National Academy of Sciences to assemble a panel of experts to assess the potential of sustainable agriculture to reduce rates of deforestation, to identify requirements for overcoming the constraints to adoption of sustainable agricultural systems, and to recommend sites for implementation of sustainable agriculture projects. Late in 1990 a series of regional workshops will be held to solicit inputs from developing countries, and an international symposium will be held early in 1991 to discuss the panel's findings.

- In May 1988, A.I.D. announced a debt-for-development initiative. This new mechanism enables A.I.D. to leverage additional fiscal resources for its development assistance efforts, including conservation. Under the program, A.I.D. supports the purchase -- normally through NGOs -- of discounted debt owed by developing countries to foreign commercial banks. Prior to the purchase, the debtor governments and NGOs work out arrangements to convert the debt to local currency that will be invested in designated projects. Resources made available under this initiative have been used for forestry projects in the Philippines and Madagascar.

- A.I.D. is providing financial support in Guatemala for the first-ever project intended to offset the carbon dioxide emissions of a particular industrial source -- a new coal-fired power plant in Connecticut. The project, which is being

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implemented by CARE in Guatemala, consists of a number of forestry interventions, which in combination are designed to sequester 387,000 tons of CO_2 per year for 40 years, or a total of 15.5 million tons, the projected emissions of the power plant over its lifetime. A.I.D.'s involvement will be to begin testing the potential of carbon sequestration forestry, an innovation which many feel holds great promise.

- A.I.D.'s recently promulgated "Initiative on the Environment" calls for analyzing the possibility of (1) increasing funding for buffer zone management (without decreasing support for parks and protected areas or natural forest management); a component of this support would be funding for interdisciplinary studies by ecological anthropologists, ecologists, and natural resource economists, linked to direct interventions to help meet the material needs of local populations on a sustainable basis; and (2) developing a comprehensive program to support natural forest management, including policy reform, in selected key countries; a minimum of 10% of A.I.D.'s total forestry budget would be reoriented to fund this program beginning in FY 1991.

6.4 A.I.D. AGRICULTURAL ACTIVITIES AND CLIMATE CHANGE

6.4.1 Introduction

Although agricultural activities are important contributors to greenhouse gas emissions, agriculture is especially significant as the sector most directly and immediately affected by climate change. A.I.D. programs that contribute to general agricultural development in developing countries, particularly to enhanced institutional capacity for research and development and to increased resilience of agricultural systems, are important components of the global response to climate change.

6.4.2 A.I.D.'s Approach to Programs and Projects

A.I.D. has only recently begun to support activities directly addressing the climate change issue, but many of the activities historically undertaken are directly or indirectly linked to the issue. The Agency has often been cited for its unique contributions to agricultural research, policy development, institution building, training, and productivity.

Training has been the cornerstone of the Agency's agricultural development strategy. University degrees and short-term training have provided many countries with the necessary human resources to conduct research, develop agricultural policy guidelines, and introduce improved technologies to the agricultural sector. Over 1300 degrees in agricultural disciplines have been awarded over the past decade within the centrally funded Collaborative Research Support Programs (CRSPs) that are conducted in partnership with the Title XII universities. Most centrally funded and country agricultural sector programs include short-term and degree training for developing country nationals. Such training is essential to enable developing countries to adapt to climate change.

The Agency has historically placed great emphasis on institutional support and development because agricultural development cannot take place in the absence of institutions to provide support in education, research, marketing, distribution and extension. A.I.D. is a major contributor to the International Agricultural Research Centers. In addition, the Agency supports regional research and educational institutions (e.g., CATIE in Central America), national agricultural universities (e.g., The National University of the Cameroon), and national agricultural research services (e.g., the Ministry of Agriculture in Indonesia). A.I.D. also supports networking and technical coordination as a cost-effective means of enabling scientists from developing countries to share information and experience. The portfolio of the Office of Agriculture in the Bureau for Science and Technology includes more than 500 scientists from over 40 countries who represent at least 50 universities and research institutions.

6.4.3 Typical and Current Programs in Agriculture

Sound policies are required to curtail emissions of greenhouse gases from agricultural systems and to stabilize food supplies in the face of climate change. The Agricultural Policy Analysis Project (APAP) is an A.I.D.-funded worldwide project devoted to increasing knowledge and understanding of the impact of key economic policies on agriculture and natural resource management. During its first 5 years of operation, APAP assisted 26 countries and all three regional bureaus in analyzing needs and options for policy reform and in developing institutional capacity for conducting agricultural policy analysis. The project has also provided a strong base of applied research and appropriate methodologies to improve policy analysis. In its second 5-year phase the project added a capability to examine relationships between agricultural policy and natural resource management.

A.I.D. developed the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) to provide decision-makers at the national and farm levels with easy access to crop model and computer expert systems to evaluate various options for sustainability in agriculture. Through this project computer models for predicting the outcomes of alternative agricultural strategies have been developed through the collaborative efforts of several scientists and institutions in the U.S. and developing countries. The IBSNAT models are being used in a joint EPA and A.I.D. project to predict the impact of climate change on crop production. Twenty-three countries are collaborating in this effort.

Many of A.I.D.'s agricultural projects are devoted to development of sustainable alternatives to shifting cultivation, especially "slash and burn", which leads to increased emissions of greenhouse gases. A.I.D. and EPA are sponsoring a state-of-the-art study by the National Academy of Sciences (NAS) to examine the role of sustainable agriculture in mitigation of deforestation in the humid tropics and to define the requirements for implementing mitigative measures. The Soil Management CRSP has, through research and development, produced sustainable technical alternatives to shifting cultivation. The Soil

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Management Support Services and Tropical Soil Moisture Management programs have focused on improved management of dryland agriculture which will likely be severely stressed by climate change.

Improvements in management of nitrogen within agricultural systems are essential to reduce emissions of oxides of nitrogen while maintaining adequate food production. The Nitrogen Fixation by Tropical Agricultural Legumes project, Soil Management CRSP, and International Fertilizer Development Center (IFDC) are conducting research activities to substitute biological nitrogen fixation for nitrogen fertilizer and to increase efficiency in the use of nitrogen fertilizer.

A.I.D.'s livestock and commodity programs contribute substantially, through research and development, to stabilization of national and global food supplies. Activities include plant breeding, water and soil management, insect and disease management, cultural practices, food quality, post-harvest management, and socioeconomic studies. The design and implementation of degree programs, management of collaborative research activities, strengthening of institutions, and baseline data surveys have been integral to these programs.

Sustainable agriculture has tremendous potential to increase the environmental compatibility of agriculture and to provide stable alternatives to shifting cultivation, which is a cause of greenhouse gas emissions. The Bureau for Science and Technology has begun planning a CRSP in Sustainable Agriculture. A.I.D. has contracted with NAS's National Research Council for assistance with the planning process. NAS is convening a panel of experts to identify the technical scope of the CRSP and to recommend managerial mechanisms to enhance interdisciplinary interaction among the agricultural, ecological, and social sciences, which is essential to the development of sustainable agricultural systems.

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CHAPTER 7

NEW A.I.D. INITIATIVES TO REDUCE GREENHOUSE GAS EMISSIONS

SUMMARY

A significant number of new A.I.D. climate change efforts in the energy, forestry and agriculture sectors are being planned. They form an integral part of broader new Agency environmental initiatives.* A.I.D. new efforts in energy include plans such as the Global Energy Efficiency Initiative, programs for supporting collaborative energy technology development and commercialization, and promotion of technology transfer in energy efficiency and clean energy technologies in developing countries. In forestry, key actions include expanded programs of policy research, training and institution strengthening focused on tropical deforestation and degradation, as well as strengthening international, multi-donor efforts to support forestry research and in-country tropical forestry assistance programs. New forestry initiatives are planned in key countries including the Philippines, Indonesia, Brazil, Mexico and Zaire, which are projected to contribute large amounts of greenhouse gases as a result of destruction of forests. Key initiatives being explored in agriculture include international collaborative programs for monitoring greenhouse emissions and soil organic carbon stocks.

7.1 INTRODUCTION

The Congressional guidance and directive contained in the Fiscal Year 1990 Foreign Assistance Appropriations Act calls upon A.I.D. to identify "specific key countries which stand to contribute significantly to global greenhouse gas emissions, and in which actions to promote energy efficiency, reliance on renewable energy resources, and conservation of forest resources, could significantly reduce emissions of greenhouse gases."

Action plans, to be credible and successful, must involve consensus and collaboration among the developed and developing countries. This chapter discusses a combination of new A.I.D. initiatives, ideas, and on-going programs, recognizing that 'new initiatives' have not been approved by official representatives of developing country governments, and therefore cannot yet be considered 'action plans'.

7.2 A.I.D INITIATIVES IN THE ENERGY SECTOR

7.2.1 The Global Energy Efficiency Initiative

A Global Energy Efficiency Initiative (GEEI) has been launched by A.I.D. with the active collaboration of an *ad hoc* working group composed of representatives from EPA, DOE, national

* See the A.I.D. document, "Initiative on the Environment," released June 28, 1990.

laboratories and non-governmental organizations. The goal of this effort is to develop, gain international support for, and implement an international program of energy efficiency, in the context of a "no-regrets" policy outlined by Secretary of State James Baker and by A.I.D. Administrator Ronald Roskens. This effort is being carried out as a part of A.I.D.'s new set of Environmental Initiatives announced by Administrator Roskens on June 28, 1990.

To reach its goal, the GEEI would sponsor six major activities:

- **Model Country Programs**: Building international consensus and support for energy efficiency programs through implementing successful and replicable model programs in certain developing countries which demonstrate the technical, economic, environmental, and social benefits of energy efficiency. Country programs that can serve as models for large-scale application are presently being solicited and reviewed.

- **Institution Building**: The GEEI would help strengthen the ability of existing institutions to plan, promote and implement energy efficiency programs. To accomplish this GEEI would organize an energy efficiency consultant group that would serve as a focal point for institution-building activities.

- **Energy Efficiency Funding**: Under GEEI A.I.D. will work with the World Bank and other multilateral and bilateral institutions to provide support for promoting energy efficiency investments in supply and end-use. These efforts will include the large-scale implementation of energy conservation and efficiency measures and projects, both for retrofit and in new installations.

- **Training**: GEEI would help establish an international consortium for training in energy efficiency to promote energy efficiency training programs. GEEI will also support private sector training programs such as those being established by the U.S. Energy Association and the U.S. Export Council for Renewable Energy.* These programs, modelled after the successful U.S. Telecommunications Training Institute, will provide training on energy technologies and management.

- **Information Networks**: GEEI would develop a worldwide information network to establish energy efficiency as a priority among key decision-makers and energy users in developing nations and Eastern Europe, and to increase international coordination and collaboration in energy efficiency. The network would enable access to data on energy efficiency performance standards, system equipment and appliance efficiencies, least-cost planning methodologies, energy policies and

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* The U.S. Energy Association is the U.S. Member Committee of the World Energy Council, an 87-nation non-governmental organization. Its members include utilities, manufacturers, government agencies, and service firms. The U.S. Export Council for Renewable Energy is a trade association dedicated to increasing sales of all forms of renewable energy.

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regulations of various countries, and other items relevant to energy conservation.

- **Global Energy Efficiency Study:** GEEI will conduct a major study of the potential for and barriers to increasing energy efficiency in developing nations. This study will help quantify the actual costs and benefits of energy conservation, raise international awareness of its potential, and develop support for implementation of comprehensive energy efficiency programs in developing countries and Eastern Europe.

7.2.2 Collaborative Technology Development and Commercialization Programs Among Industrialized and Developing Countries

Developing countries face massive, daunting problems in meeting their electric power needs for economic development in ways that are financially and environmentally acceptable. Serious capital and managerial constraints complicate the task of introducing environmental protection measures, whether local or global. Only about $10 billion of the projected requirements of $100 billion per year to support electric power development will be available from external sources, and the decline in financial performance of power utilities in developing countries will make internal capital mobilization very difficult.

In industrialized countries, the threat of global warming from greenhouse gas emissions, including carbon dioxide production from fossil fuel combustion, has prompted a search for energy and industrial strategies and policies that can ensure economic growth and, at the same time, substantially reduce greenhouse gas emissions. In the developing countries, current financing for technology development and commercialization is insufficient to make a major impact. Furthermore, multilateral development banks and international financing institutions are technologically risk averse. Yet, such institutions do not finance technology research, development, and commercialization, but do play an important role in emphasizing efficiency, power systems management, and policy reform.

Innovative approaches on all fronts will be necessary. Neither policy reforms nor institutional strengthening, nor technological innovation alone can solve the problem of increasing the per capita delivery of electrical services in developing countries ten-fold under severe capital and environmental constraints. A multifaceted approach will be necessary, posing a difficult challenge for the international community.

Indian and U.S. participants in the April 1990 PACER (Program for Acceleration of Commercialization Energy Research) Conference in New Delhi proposed establishment of a mechanism to raise $1 billion per year to support the development and commercialization of innovative electric power technologies for generation and end use that would support the economic goals of developing countries and contribute to reducing greenhouse gas emissions. Conference participants suggested that the funds

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could be created from a global carbon user's fee of about $0.02 per barrel of oil or $0.084 per ton of coal. For India the national contribution would be about $24 million per year; for the U.S. it would be close to $235 million dollars annually. The concept of such a carbon emissions surcharge is still controversial; however, it (as well as schemes for international trading of emissions rights) is now being discussed extensively in the international energy/environment community, and needs to be explored along with other mechanisms. A.I.D. has not taken a position on the desirability of this approach.

7.2.3 Formation of an International Electric Utility Industry Network

A.I.D. representatives have met with senior executives from the Electric Power Research Institute (EPRI) in the U.S. and from utilities in Western Europe, Japan, Canada, India, China and Brazil to explore the possibility of forming an International Electric Utility Industry Network to sponsor collaborative research and technology development related to climate change. EPRI has an international reputation for sponsoring and managing research and development relevant to the needs of the U.S. electric utility industry, for financing the commercialization of innovative electric power technology, and for providing objective, independent, and high-quality technical documentation.

In developing and implementing its power sector assistance programs, A.I.D. has often drawn on expert advice and assistance from the U.S. electric utility industry and from EPRI. EPRI's example in sponsoring technology development and commercialization can guide others who are constructing a global climate-sensitive energy research and development strategy.

Several of the developing countries that A.I.D. works with have relatively sophisticated and growing electric power sectors. Some of these countries face special challenges in implementing supply- and demand-side efficiency measures. Many of the innovative approaches that will be required to address LDC electric utility needs and problems in the future will require a new international participatory network.

A.I.D. works closely within the MAGPI framework to identify and develop practical projects designed to catalyze innovation in the LDC electric power sector. For many of these activities, a technical and financial partnership with R&D institutions and commercial organizations in the industrialized countries will be required to catalyze bankable projects leading to the successful introduction and diffusion of the needed technological capabilities. As part of its assistance to countries such as India, Pakistan, Thailand, and Egypt, the Agency is increasingly called upon to play the role of an international EPRI.

Many government and donor agencies have recognized that significant indigenous innovation will be required to increase the technical performance and financial viability of LDC electric utilities, in part through pricing reform, initiative changes, management improvements, increases in power plant efficiency

and capacity factors, reduced transmission and distribution losses, and significantly increased end-use efficiency in all sectors.

Areas of primary concern that strongly suggest the usefulness of an International Electric Utility Industry Network include the following:

- The need to disseminate information about successful experiences with integrated or least-cost power sector planning, i.e., comprehensive planning that puts energy efficiency and conservation on an equal footing with power generation;
- Research, technology development, and commercialization of more environmentally sound energy technology, including the rehabilitation of existing power plants, clean fossil technology, efficiency, and renewable power generation systems;
- Training programs in least-cost planning, energy efficiency, and renewables, involving U.S. utilities, EPRI, and the Edison Electric Institute, as well as the utilities of OECD countries;
- Access to software tools for environmental management, power sector planning, and systems operation; and
- Access to media materials (films, videotapes, slides, graphics) providing authoritative technical, economic, and environmental information on electric power systems technology.

7.2.4 Promoting U.S. Exports of Clean Energy Technologies

Increased promotion of U.S. exports of energy efficient and renewable energy technologies would help developing countries meet their growing energy needs, contribute to reductions in the U.S. trade deficit, and may help limit the economic burden, for both the U.S. and developing countries, of meeting future greenhouse gas emission reduction requirements. It would support the adoption of energy efficient and renewable energy technologies in developing countries by combining the technical leadership of the U.S. industry, A.I.D.'s close working relationship with developing countries, and additional technical resources from other agencies, such as DOE and EPA. While the developing countries would benefit from the transfer of technologies, financial investment, and technical services to meet their growing energy demand, the U.S. would benefit by gaining a greater competitive edge in international markets and reducing its trade deficit. In the longer term, all countries would benefit from a safer environment and lower energy prices, as increased sales reduce the costs of these technologies.

The rapid growth in demand for energy in a number of developing countries has put tremendous pressures on their financial, institutional, and natural resources. In some countries this growing demand

is leading to significant shortfalls in electricity-generating capacity; for example, Pakistan is currently confronting a shortfall of more than 30%. Additionally, to meet the demand for petroleum in their transportation sectors, countries have had to commit significant portions of their foreign exchange earnings. The increased use of traditional fuels, particularly wood and charcoal, is a major factor in deforestation. As energy use has risen, air and water quality in many locations has been severely degraded. In addition, continued growth in demand will soon make several countries (e.g., China, Brazil, and India) significant contributors to global warming, with a number of others not far behind.

This situation warrants a more aggressive policy to support the development and adoption of alternative energy options. The U.S., as a leader in energy efficiency and renewable energy products, services, and know-how, can make a significant contribution to helping developing countries meet their needs for reliable, clean energy. A.I.D. can contribute to the development of a more focused U.S. strategy that combines export promotion, technology transfer, and training to assist developing countries in this effort. These countries would benefit in the near term by having quicker access to and support in the use of advanced technologies, and over the long run by having improved opportunities for joint ventures that would encourage more local manufacturing of energy system components.

Increasing exports would benefit U.S. firms who would realize higher sales and benefit from a stronger market base. The nation, in turn, would benefit from lower trade deficits. A significant effort to penetrate developing country markets now would also put U.S. industry in a better position to benefit from increased demand for clean energy technologies, which could occur as a result of future limitations on greenhouse gas emissions. To the benefit of both developing countries and the U.S., additional sales of energy-efficient and renewable energy technologies would eventually lead to lower energy costs, a particularly important benefit if it reduces the burden of greenhouse gas emission reductions. Energy costs would be reduced if manufacturers took advantage of increased economies of scale in their production processes and passed on the savings.

To take advantage of these opportunities, U.S. firms must be able to compete in international markets against foreign firms, which often receive direct government support in the form of aid programs, subsidized loans, protected markets, and other assistance. The U.S. has resisted participating in these unfair trade practices, yet it does fund a number of programs to support U.S. industry. A.I.D. is exploring ways in which the Agency could significantly expand its participation in and support for these programs as a means of giving developing countries greater access to U.S. technology and know-how and helping U.S. industry compete overseas.

7.3 A.I.D. INITIATIVES IN THE FORESTRY SECTOR

Both Congress and A.I.D. have recognized the need to address problems posed by unwarranted deforestation in tropical areas. Section 118 of the Foreign Assistance Act authorizes A.I.D. to increase its tropical forest development and conservation activities. A.I.D.'s April 1988 policy paper entitled "Environment and Natural Resources" recognized tropical forests as a special concern and declared it to be A.I.D. policy to:

(a) engage in policy dialogues that stress (1) the importance of conserving and managing forest resources for long-term benefit, (2) the importance of appropriate economic incentives and tenure policies, 3) local participation in sustainable management structures, and (4) the key role of the private sector, including farmers, NGOs and private business, in sustaining forestry programs;

(b) promote the management of existing forests for sustainable yields . . .

(c) provide alternatives to forest destruction . . .

(d) conserve natural forests and support the conservation of forested watersheds, establishment of forest reserves managed for research on natural forest processes, and designation of biosphere reserves that protest ecosystems representative of particular forest types; and

(e) restore forest resources and support efforts to expand tree planting . . .

On June 28, 1990, A.I.D. issued its "Initiatives on the Environment" which inter alia set forth technical and policy areas of intervention in response to major environmental issues. Tropical forestry is prominent among these because "deforestation and unsustainable use and degradation of tropical forests result in enormous and often unrecoverable economic and social costs." Environmentally sound agriculture is also addressed, in part because in many regions of the world unsustainable agricultural production systems contribute to deforestation.

7.3.1 Collaborative Program to Improve Management of Natural Tropical Forests and Reduce Deforestation Rates

A.I.D. proposes to expand policy development, research, technical assistance, technology development and diffusion, institutional strengthening, and training programs designed to reduce tropical deforestation and to encourage sustainable management of natural tropical forests.

Tropical deforestation is occurring at an alarming, and probably accelerating, rate -- approximately 1% of the present stock, or 17 million hectares of forest, is lost each year, according to recent FAO estimates. Moreover, the quality of the remaining stock is being degraded, reducing its capacity to

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perform a multiplicity of essential functions. Tropical forests provide wood for industry and local use, fruits, nuts, medicinal and other products, soil and watershed protection, climate control and other environmental services, and also serve as habitat for more than half of the world's plant and animal species. At current estimated rates, tropical deforestation may account for as much as one-third of total global carbon dioxide emissions. But despite the economic and environmental benefits that forests offer, pressures of growing populations of poor people and the foreign exchange requirements of international debt are leading to their unsustainable use and conversion in many developing countries. Moreover, market failures and misguided land development, land tenure, tax and investment policies, inappropriate incentives, and other policy distortions seriously exacerbate the problem.

The time is right for an expanded program of policy research, technical assistance, technology development and diffusion, institutional strengthening, and training focused on the tropical deforestation and degradation problem, both as a response to the threat of global climate change and to the need to use a valuable, indeed irreplaceable, resource for development purposes. More specifically, these initiatives by A.I.D. will include:

- **Collaborative efforts to strengthen international tropical forest research and the institutional mechanisms to carry it out.** These efforts will involve strengthening existing national and regional programs, international research institutions, and forestry research networks, and examining options for additional mechanisms that may be required. A.I.D. will play an active role within the bilateral and multilateral donor community to promote this agenda. Institutions presently involved in this effort include the Consultative Group for International Agricultural Research and its international research centers, the International Union of Forestry Research Organizations, the International Council of Research in Agroforestry, forestry and other research institutions in developing countries, forestry research networks such as the Asian Network on Multi-Purpose Free Research supported by A.I.D. (the F/FRED project), and others.

- **Strengthening worldwide in-country implementation of tropical forestry assistance.** Significant attention will be given to reforming, restructuring, and improving the Tropical Forestry Action Plan (TFAP), and working with other donors, FAO, the developing countries, and the NGO community.

- **Expanded technical services** in forest management, agroforestry, buffer zone development, conservation, and nature tourism.

- **Research and analysis** geared toward development and implementation of sustainable resource management options and policy packages to identify and address important causes of tropical deforestation and degradation, market failures, and policy distortions.

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- **Strengthening the institutional and human resource capabilities** which are needed in developing countries to carry out research and develop and implement appropriate policies and programs on a continuing basis.

7.3.7 Expanded Program to Conserve and Sustainably Manage Tropical Forests in "Key" Countries

New forestry initiatives are going forward on those "key" countries where deforestation is a major source of greenhouse gas emissions. Significant examples include:

Philippines

A major new environment and natural resource project beginning in FY 1990 includes support for forestry policy and management as well as a debt-for-nature swap. Planned obligations for FY 1990 are $24 million.

Indonesia

A new $18.5 million Environment and Natural Resources project is under preparation. It will address both environmental policy issues and sustainable management of Indonesia's extensive tropical forests. An interesting feature of this project is expected to be its focus on policy development through an applied research program that links the government's forestry research agency with a private-sector forest concessionaire. The private sector is the key direct manager of forest resources, but it is not yet adequately involved in identifying and addressing constraints to sustainable forest sector management.

Brazil

The primary focus of the program will be on promoting sustainable forest use, inter alia by synthesizing existing information and developing new knowledge about what works, what doesn't work, and why -- in terms of sustainable land-use systems in the ecologically diverse Amazon region. Proposed activities include support for research and workshops involving Brazilian and U.S. experts on natural resource economics, ecology, forestry, agroforestry and related fields, as well as support for existing consortia of NGOs and government institutions that are developing and promoting the sustainable use of Amazonian resources. Activities of these consortia include: policy analysis, research, evaluation and dissemination of information on sustainable forestry and agroforestry, training, ecotourism, and the establishment of parks and extractive reserves.

Mexico

A.I.D. plans to place major emphasis on promoting the conservation and rational management of Mexico's forest resources, particularly in the tropical and subtropical forests of southern Mexico (i.e.,

in areas contiguous with Central America, which has also been identified as a "key" region). Activities will include a workshop on global climate change to increase public awareness of the problem, its implications, and what can be done about it; operational support (equipment, supplies, technical assistance, and training) for completing and implementing management plans for eight priority protected areas in southern Mexico; socioeconomic studies oriented toward buffer zone management needs in these same protected areas, development of income-generation techniques and alternatives to deforestation; community development pilot projects in buffer zones to test alternative forest use approaches, such as natural forest management and extractive reserves; assistance for micro-enterprise development and community watershed protection; and training and environmental education for local inhabitants.

Zaire

A.I.D. has proposed a new $2 million global climate change initiative in Zaire, which has been incorporated into the country action plan. U.S.A.I.D./Zaire has amended its Small Project Support Project (SPSP) to provide additional funding for small-scale community development projects in the Shaba and Bandundu regions. The SPSP also has extended its funding reach beyond these regions to fund a proposed project in the Ituri Forest, Africa's largest remaining tropical forest. The mission is also interested in collaborating with other international donors on a debt-for-nature exchange to leverage more funding for conservation/development projects to address natural resource management and energy-use issues. Medium- and long-term activities to address global climate change will be developed in the near future.

7.4 A.I.D. INITIATIVES IN THE AGRICULTURE SECTOR

7.4.1 International Collaborative Program for Monitoring and Increasing Stocks of Carbon in Soil Organic Matter

The establishment of a global network will be explored to monitor stocks of carbon in soil organic matter at existing long-term research sites in developed and developing countries and to relate changes in stocks to land-use management. The program would be cost effective as it would draw on existing programs.

Soil organic matter is the largest terrestrial stock of carbon, and increases in this stock have tremendous potential to reduce the net increase in atmospheric carbon dioxide. The IPCC Workshop on Greenhouse Gas Emissions from Agricultural Systems identified this potential, but also pointed out that there is little knowledge concerning the relationship between rates of carbon additions to or loss from the soil stock and land-use management. Soil organic matter is also a source of carbon dioxide emissions, especially when there are changes in land-use. Cultivation of soils, burning of grasslands, and

deforestation typically expose soil organic matter to oxidation which results in emission of carbon dioxide. The IPCC workshop noted that there is a dearth of information on stocks of carbon in soils, rates of gaseous emissions, and the dynamics of the carbon cycles within various land-use management practices.

A.I.D. is in a unique position to increase information on stocks and changes in stocks of soil organic carbon. A.I.D. collaborates with universities and national and international research institutions who manage hundreds of research sites in developed and developing countries. These sites represent a range of ecological zones, soil types and management practices, and frequently have well-documented histories of land-use management. Modest investment of additional funds in these existing sites and programs would be an extremely cost-effective means of filling these critical gaps in our knowledge. A.I.D. will explore this possibility.

7.4.2 International Collaborative Network for Monitoring Greenhouse Gas Emissions from Terrestrial Ecosystems

A global network to monitor greenhouse gas emissions could be established at existing long-term research sites in developed and developing countries which would also relate emissions to land-use management. The effort would be extremely cost effective as it capitalizes upon existing programs.

The IPCC Workshop on Greenhouse Gas Emissions from Agricultural Systems concluded that agricultural systems are significant sources of greenhouse gases, that there is little information on rates of emissions and that there is practically no information on the relationships between emissions and land-use management.

Nitrous oxide, methane and carbon dioxide emissions result from the disruption of nitrogen and carbon cycles in terrestrial ecosystems. Knowledge of these cycles, which is currently very limited, is essential to management for reducing emissions from terrestrial ecosystems.

A.I.D. is in a unique position to increase information on gaseous emissions from terrestrial ecosystems and to relate such emissions to land-use management. A.I.D. collaborates with universities and national and international research institutions who manage hundreds of research sites, both in developed and developing countries, that represent a range of ecological zones, soil types and management practices. Because these sites frequently have well-documented histories of land-use management, a modest investment of additional funds to conduct research at these existing sites and programs would be an extremely cost-effective means of filling these critical gaps in our knowledge. A.I.D. will explore this possibility.

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7.4.3 Sustainable Agricultural Systems Collaborative Research Support Program

A.I.D. has begun the planning process to implement in FY 1991 a Sustainable Agricultural Systems Collaborative Research Support Program (CRSP) that will integrate agricultural, environmental and social sciences within A.I.D.'s agricultural portfolio.

Promotion of sustainable agriculture is a logical way for A.I.D. to respond to the challenges of environmental degradation in the rural landscapes of developing countries. Over 30% of A.I.D.'s portfolio is in agriculture and rural development. Agricultural systems, especially paddy rice, animals, and grasslands which are burned, are significant contributors to atmospheric greenhouse gases. In addition, slash-and-burn agriculture is the major contributor to deforestation. Major environmental problems within rural landscapes (e.g., deforestation, desertification, erosion, and soil degradation) also lead to greenhouse gas emissions.

A research program in sustainable agriculture offers opportunities to make reduction of greenhouse gases an explicit goal within agricultural systems. Alleviation of the major environmental problems referenced above through development of sustainable alternatives, including alternative technologies which could significantly decrease forest destruction to increase land available for agriculture, will also reduce greenhouse gas emissions from agricultural systems.

A.I.D. has contracted with the National Research Council of the National Academy of Sciences to direct the planning process for the Sustainable Agricultural Systems Collaborative Research Support Program (CRSP). The Academy's final report, scheduled for submission in February 1991, will contain recommendations for the technical scope-of-work, appropriate research sites in developing countries, and criteria for selecting grantees to conduct the CRSP. The CRSP will be awarded in FY 1991 through a competitive bidding process.

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Technical Annex

GREENHOUSE GAS EMISSIONS AND THE DEVELOPING COUNTRIES: STRATEGIC OPTIONS AND THE U.S.A.I.D. RESPONSE

A Report to Congress

July 1990

U.S. Agency for International Development
Washington, DC

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

This background document supports the data and methodology presented in the U.S. Agency for International Development report, "Greenhouse Gas Emissions and Developing Countries: Strategic Options and the U.S.A.I.D. Response." Chapter 2 of this background document provides additional material on population and economic growth as well as greenhouse gas emissions by source and region for Chapter 2 of the main report on contributions of developed and developing countries to greenhouse gas emissions. Chapter 3 of this background document presents a more detailed discussion of the potential greenhouse gas emission scenarios developed by the Energy and Industry Subgroup (EIS) and the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) of the Response Strategies Working Group (RSWG) of the Intergovernmental Panel on Climate Change (IPCC), discussed in Chapter 3 of the main report. Chapter 4 of this document provides background information on the discussion in Chapter 4 of the main report on the potential reductions in emissions the international community may be able to achieve while maintaining economic growth.

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CHAPTER 2

BACKGROUND DOCUMENTATION ON CURRENT CONTRIBUTIONS OF DEVELOPED AND DEVELOPING COUNTRIES TO GREENHOUSE GAS EMISSIONS

2.1 INTRODUCTION

This chapter provides background material for Chapter 2 of the main report, which described current emissions of greenhouse gases and their contribution to climate warming. Estimates of emissions were presented on a CO_2-equivalent basis in Chapter 2 of the main report; here, emission estimates are presented in the more conventional units, i.e., CO_2 in teragrams of carbon (Tg C), CH_4 in teragrams CH_4 (Tg CH_4), N_2O in teragrams of nitrogen (Tg N), and CFCs in gigagrams of each chemical (Gg based on full molecular weight).[a,b]

2.2 POPULATION AND ECONOMIC GROWTH

Table 2-1 presents current statistics on population and economic growth, two key factors which in part are responsible for regional variations in greenhouse gas emissions. Developing countries, with the highest population growth rates in the world, have the lowest absolute levels of GDP as well as GDP/capita.

2.3 GREENHOUSE GAS EMISSIONS

Table 2-2 presents estimates of current emissions of the major gases by source and by region that were used to generate Figure 2-1 of Chapter 2 of the main report. Regional estimates were available from the scientific literature for CO_2 from fossil fuels, deforestation, and cement, and for CH_4 from livestock and animal wastes.[c,1,2,3,4] Regional estimates of the other gases were derived from global (or broad regional) estimates using regional statistics on the human activities that affect emissions. Global estimates of methane emissions from rice cultivation, biomass burning, and fossil fuel production were disaggregated into country-specific emissions using data on harvested rice area, tropical deforestation, and coal mining and natural gas production.[5,6,2,7,8] Regional estimates of CH_4 emissions from landfills

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[a] 1 Tg = 10^{12} grams = 10^6 t = 1 million metric tons.

[b] 1 Gg = 10^9 grams = 10^3 t.

[c] Recent data indicates that animal wastes are a significant source of methane. Therefore, we have incorporated these emission estimates into the regional disaggregation of emissions. Animal waste emissions are not included in Figure 2-3 since no one has yet incorporated these estimates into a published comprehensive CH_4 budget.

were disaggregated based on country-specific GNP/capita and population data.[9,10] Global estimates of nitrous oxide emissions from fertilizer use, biomass burning, gain in cultivated land, and fossil fuel combustion were disaggregated into country-specific emissions based on data on nitrogen fertilizer consumption, tropical deforestation, and fossil fuel consumption.[11,12,13,2,8] Regional estimates of CFC emissions were based on regional production estimates; these were disaggregated into country-specific emissions based on population.[12,9]

TABLE 2-1

RECENT POPULATION AND ECONOMIC INDICATORS

	1985 Population (millions)	Average Annual Population Growth (%) 1980-1985	1985 GDP (billions of dollars)	Average Annual GDP Growth (%) 1980-1985	1985 GDP per capita ($1,000/cap)
Low- and middle income economies[a]	3,705	2.0	2,496	3.4	0.67
Low-income economies	2,709	2.0	815	5.9	0.30
Middle-income economies	996	2.2	1,681	2.2	1.69
Sub-Saharan Africa	415	3.1	185	-0.5	0.45
Zaire	31	3.0	5	1.0	0.16
East Asia	1,465	1.5	629	7.8	0.43
China	1,040	1.2	266	9.8	0.26
Indonesia	162	2.1	86	3.5	0.53
Philippines	55	2.5	33	-0.5	0.60
South Asia	1,033	2.3	277	5.4	0.27
India	765	2.2	176	5.2	0.23
Pakistan	96	3.1	28	6.0	0.29
Europe, Middle East, and North Africa	374	2.0	470	2.3	1.26
Poland	37	0.9	70	0.5	1.89
Latin America and the Caribbean	387	2.2	682	0.5	1.76
Brazil	136	2.3	188	1.3	1.38
Mexico	79	2.6	177	0.8	2.24
Rest of Central America	25	1.0-3.5	29	-1.8-2.4	1.16
17 highly indebted countries	556	2.4	826	0.2	1.49
High-income economies[a]	867	0.7	8,933	2.3	11.65
OECD members	738	0.6	8,693	2.4	11.78
Total reporting economies	4,472	1.8	11,431	2.6	2.56

[a] This regional classification system is based on per capita income. Low-income economies are those that had a GNP per capita of $480 or less in 1987, middle-income economies are those that had a GNP per capita of more than $480 but less than $6,000 in 1987, and high-income economies are those that had a GNP per capital of $6,000 or more in 1987.

Sources: Regional data from World Bank (1989);[9] Key country data from World Bank (1987).[14]

Table 2-2

Regional Anthropogenic Greenhouse Gas Emissions
1985

REGION	CO_2 EMISSIONS (Tg C)				CH_4 EMISSIONS (Tg CH_4)					N_2O EMISSIONS (Tg N)			CFCs AND OTHER MANMADE CHEMICALS[c] (Gg)					
	Fossil Fuel Combustion	Deforestation/ Reforestation	Cement Production	Total	Rice Production	Livestock	Fossil Fuel Production	Other[a]	Total	Fertilizers	Other[b]	Total	CFC-11	CFC-12	HCFC-22	CFC-113	CCl_4	CH_3CCl_3
OECD	2,504	36	47.1	2,588	2.6	19.2	21.5	36	78	1.0	0.6	1.6	186	231	66	131	58	622
Eastern Europe/USSR	1,325	24	27.0	1,376	0.6	10.5	18.2	14	43	0.2	0.3	0.5	34	72	4	9	14	68
Poland	119	-2	0.7	118	0.0	0.8	3.1	2	6	0.02	0.02	0.04	3	6	<1	1	1	6
Centrally-Planned Asia	542	195	20.7	757	31.0	5.1	15.4	10	61	0.2	0.3	0.5	5	9	1	1	2	12
China	503	69	19.4	591	24.3	4.4	14.6	6	49	0.2	0.2	0.4	2	6	<1	1	1	7
Middle East	133	4	6.0	143	<1	1.0	0.8	1	3	0.01	0.03	0.04	3	3	<1	1	1	3
Africa	165	378	5.6	547	4.1	9.1	2.6	14	30	0.01	0.4	0.4	17	16	<1	3	4	2
Zaire	1	35	0.1	36	<1	0.1	0.002	1	1	0.00	0.03	0.03	1	1	1	<1	<1	29
Latin America	220	665	9.7	895	5.3	15.7	1.3	25	47	0.04	0.7	0.7	12	11	1	2	3	20
Brazil	41	336	2.6	380	3.6	7.5	0.1	12	23	0.01	0.3	0.3	4	4	<1	1	1	7
Mexico	68	33	2.9	104	<1	1.5	0.4	2	4	0.01	0.05	0.1	3	2	<1	<1	1	4
Rest of Central America	4	52	0.4	313	<1	0.4	0.0	2	2	0.003	0.1	0.1	1	1	<1	<1	<1	1
South and East Asia	266	492	13.9	772	65.2	15.3	2.7	21	104	0.1	0.5	0.7	21	22	2	4	6	38
India	98	33	4.5	135	31.8	10.3	1.6	5	48	0.07	0.1	0.1	2	4	<1	1	1	5
Indonesia	22	192	1.4	215	7.2	0.4	0.3	6	14	0.02	0.2	0.2	5	5	<1	1	1	6
Pakistan	12	1	0.7	14	1.5	1.5	0.1	1	4	0.01	0.004	0.02	3	3	<1	1	1	5
Philippines	8	57	0.4	66	2.6	0.2	0.01	2	5	0.002	0.1	0.1	2	2	<1	4	<1	3
Thailand	12	95	1.1	108	7.2	0.5	0.03	3	11	0.003	0.1	0.1	2	1	<1	<1	<1	3
World	5,155	1,792	130	7,077	109.4	75.7	62.4	120	367	1.6	2.9	4.5	278	364	74	151	67	813

[a] Other includes biomass burning, animal wastes, and landfills.

[b] Other includes biomass burning, land clearing, and fossil fuel combustion.

[c] These emission estimates are highly uncertain. They are based on global and regional production estimates disaggregated by regional and country population statistics.

Sources: Marland et al. (1989);[1] Houghton et al. (1987);[2] FAO (1986);[15] Cicerone and Oremland (1988);[5] IRRI (1988);[6] Lerner et al. (1985);[3] Fung and Matthews pers. communication; Crutzen et al. (1979);[16] Bingemer and Crutzen (1987);[19] United Nations (1987);[8] Bolle et al. (1986);[11] FAO (1987);[13] U.S. EPA (1990).[12]

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CHAPTER 3

BACKGROUND DOCUMENTATION ON THE POTENTIAL CONTRIBUTIONS OF DEVELOPING COUNTRIES TO GREENHOUSE GAS EMISSIONS ASSUMING NO POLICY ACTIONS

This study relies on the greenhouse gas emission scenarios developed by the Energy and Industry Subgroup (EIS) and the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) of the Response Strategies Working Group (RSWG) of the Intergovernmental Panel on Climate Change (IPCC). Key components of these scenarios are discussed below.

3.1 POPULATION GROWTH

Two approaches were used to develop the population estimates for the IPCC. For the EIS/AFOS Reference case, population estimates were provided by each of the participating countries. In order to compile a complete global population estimate, World Bank population projections for countries not participating in the development of the EIS/AFOS Reference Case were used.[1]

For the Task A scenarios, the World Bank population estimates were used and were not varied among scenarios. The World Bank assumed that population growth rates in developing countries will begin to decline markedly after 2000, achieving a net reproduction rate of unity in every country by 2040. (A net reproduction rate of unity indicates that people of child-bearing age have children at a replacement rate; it eventually leads to a stable population level.) These estimates project a global population of 8.2 billion by 2025.[a] Detailed population estimates for these two approaches, including estimates for the key countries, are summarized in Table 3-1.

3.2 ECONOMIC GROWTH

For the EIS/AFOS Reference case, the economic growth estimates were provided by the individual country participants based on their best estimate of moderate economic growth for their countries. If a country was not participating in the development of the EIS/AFOS Reference case, information provided by the International Energy Agency[2] was used to develop economic growth estimates.[3] In the Task A scenarios, rates of economic growth were derived from estimates from the World Bank to reflect a range of economic activity, i.e., rates that were higher and lower than recent historical experience were developed.[4] The economic growth estimates from these various approaches are summarized through the year 2025 in Table 3-2.

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[a] Under other scenarios considered plausible by many experts, global population could grow to about 14 billion by 2050.

TABLE 3-1

GLOBAL POPULATION LEVELS THROUGH 2025
(millions)

REGION	EIS/AFOS Reference 1985	2000	2025	Task A Report 1985	2000	2025
United States	239	270	298	239	267	289
OECD Europe/Canada	430	456	477	430	459	483
OECD Pacific	144	159	170	144	158	166
Eastern Europe/USSR	416	472	551	416	454	500
Poland	37	40	43	37	41	45
Centrally Planned Asia	1,145	1,292	1,563	1,140	1,408	1,728
China	1,045	1,172	1,420	1,040	1,274	1,537
Middle East	111	172	277	111	171	277
Africa	570	871	1,498	570	872	1,498
Zaire	NA	NA	NA	31	47	80
Latin America	402	512	711	402	530	715
Brazil	132	159	214	136	178	236
Mexico	83	105	155	79	110	154
Rest of C. America	NA	NA	NA	25	36	54
South and East Asia	1,405	1,758	2,434	1,417	1,858	2,534
India	751	926	1,315	765	996	1,312
Indonesia	165	198	267	162	212	283
Pakistan	NA	NA	NA	96	146	242
Philippines	NA	NA	NA	55	75	105
World	4,862	5,963	7,979	4,870	6,176	8,190

Sources: U.S./Japan Expert Group Report (1990);[3] Zachariah and Vu (1988).[1]

TABLE 3-2

ECONOMIC GROWTH RATE ASSUMPTIONS
(average annual growth rates in GDP)
(%/year)

	EIS/AFOS Reference			Task A Report			
				Lower Growth		Higher Growth	
	1985-2000	2000-2025	1985-2025	1985-2000	2000-2025	1985-2000	2000-2025
GLOBAL AVERAGE	**3.2**	**2.9**	**3.0**				
North America	**2.6**	**2.0**	**2.2**	**2.0**	**1.5**	**3.0**	**2.5**
Western Europe	**2.6**	**2.1**	**2.3**	2.0	1.5	3.0	2.5
OECD East	**3.9**	**2.7**	**3.1**	**2.5**	**1.5**	**3.5**	**2.5**
Eastern Europe/USSR	**3.3**	**3.1**	**3.2**	**2.6**	**2.1**	**4.6**	**4.1**
Poland	2.5	2.9	2.8	2.6	2.1	4.6	4.1
Africa	**2.8**	**4.7**	**4.0**	**3.0**	**2.6**	**4.5**	**4.0**
Zaire	NA	NA	NA	2.2	1.7	4.2	3.7
Cent Plan Asia	**5.2**	**5.4**	**5.3**	**3.5**	**3.0**	**5.5**	**5.0**
China	5.6	5.6	5.6	3.6	3.1	5.6	5.1
Latin America	**2.8**	**3.5**	**3.3**	**2.7**	**2.2**	**4.7**	**4.2**
Brazil	3.2	3.2	3.2	2.9	2.4	4.9	4.4
Mexico	3.5	3.5	3.5	2.6	2.1	4.6	4.1
Rest of C. America	NA	NA	NA	2.6	2.1	4.6	4.1
Middle East	**5.4**	**4.6**	**4.9**	**3.3**	**2.8**	**4.1**	**4.6**
South & East Asia	**4.5**	**4.6**	**4.6**	**3.3**	**2.8**	**5.3**	**4.8**
India	4.9	4.9	4.9	3.6	3.1	5.6	5.1
Indonesia	3.0	3.0	3.0	3.6	3.1	5.6	5.1
Pakistan	NA	NA	NA	3.6	3.1	5.6	5.1
Philippines	NA	NA	NA	2.6	2.1	4.6	4.1

Sources: U.S./Japan Expert Group Report (1990);[3] Task A Report (1990).[4]

3.3 EMISSION SCENARIOS ASSUMING NO RESPONSE TO CLIMATE CHANGE

This section summarizes emissions under various economic growth assumptions when no policy actions are assumed to be taken by the international community to reduce greenhouse gas emissions.

3.3.1 Emissions from Energy

The largest source of greenhouse gas emissions is the use of fossil fuels. In the IPCC scenarios, annual global primary energy supply increases from about 306 exajoules (EJ) in 1985 to 473 EJ (2030 Emissions/Lower Growth) - 737 EJ (EIS/AFOS Reference) by 2025.[b] Table 3-3 summarizes fuel use by type. Table 3-4 summarizes the regional differences in energy use and CO_2 emissions.

Key Countries

The only study for which analyses of greenhouse gas emissions from individual countries was provided was the EIS/AFOS Reference case. The study for China was prepared by government representatives on a preliminary basis, while the remaining country studies were prepared by independent experts and submitted to the IPCC for consideration in its proceedings. Table 3-5 summarizes major parameters for the key countries for which data were available.

TABLE 3-3

GLOBAL PRIMARY ENERGY SUPPLY IN BASELINE SCENARIOS (Exajoules/year)

		2025		
		EIS/AFOS	"2030 Emissions Case"	
	1985	Reference	Lower Growth	Higher Growth
Coal	86	238	159.1	276.8
Oil	121	223	142.8	153.7
Gas	59	173	90.3	105.5
Hydro	19	57	43.5	48.7
Other	21	46	36.6	72.3
TOTAL	306	737	472.3	657.0

Sources: U.S./Japan Expert Group Report (1990);[3]
Task A Report (1990).[4]

[b] 1 Exajoule = 1 EJ = 10^{18} joules; 1 Exajoule = 0.95 quadrillion Btus

TABLE 3-4

ENERGY AND CO_2 RESULTS FROM THE BASELINE SCENARIOS

REGIONS	Energy Use in 2025 Exajoules				CO_2 Emissions in 2025 (Pg C)			
			"2030 Emissions"				"2030 Emissions"	
	1985	EIS/AFOS Reference	Lower Growth	Higher Growth	1985	EIS/AFOS Reference	Lower Growth	Higher Growth
United States	77.2	111	96.4	111.2	1.4	2.1	1.7	2.0
OECD Europe/Canada	62.9	103	77.1	91.7	0.8	1.4	1.1	1.3
OECD Pacific	19.2	39	22.1	24.9	0.3	0.6	0.4	0.4
Eastern Europe/USSR	74.9	166	128.5	143.2	1.4	2.8	2.3	2.7
Centrally Planned Asia	24.5	88	46.2	87.9	0.5	1.8	1.0	2.0
Middle East	7.7	43	28.6	34.4	0.1	0.7	0.5	0.6
Africa	8.7	46	12.8	31.6	0.2	0.8	0.2	0.6
Latin America	15.7	49	32.4	65.8	0.2	0.6	0.4	0.9
South and East Asia	15.1	92	28.6	66.4	0.3	1.6	0.5	1.2
TOTAL	305.9	737	472.7	657.1	5.2	12.4	8.1	11.7

Sources: U.S./Japan Expert Group Report (1990);[3] Task A Report (1990).[4]

TABLE 3-5

SUMMARY RESULTS FROM EIS/AFOS REFERENCE CASE: KEY COUNTRIES

Country	GDP Growth (index)		Primary Energy (exajoules)			CO_2 Emissions (million tons C)		
	1985	2025	1985	EIS/AFOS 2025	AAGR[a] (%) 1985-2025	1985	EIS/AFOS 2025	AAGR[a] (%) 1985-2025
Brazil	100	358	6.0	15.2	2.7	41	129	2.9
China	100	877	29.0	86.0	2.8	503	1,719	3.0
India	100	669	8.1	36.6	3.8	98	620	4.0
Indonesia	100	332	1.8	9.3	4.2	22	141	4.4
Mexico	100	396	4.5	12.0	2.5	68	199	2.5
Poland	100	296	5.3	11.4	1.9	119	255	1.9

[a] AAGR - average annual growth rate in percent/year.

Source: U.S./Japan Expert Group Report (1990).[3]

Other Energy Studies

Other organizations also produce forecasts of global energy use, using diverse methodologies in order to address various concerns. These estimates provide additional comparisons to the scenarios developed by the IPCC. Three studies provide a range of forecasts:

- The International Energy Agency forecast used in constructing the EIS/AFOS Reference case extends to the year 2005;[2]
- The Commission of the European Communities gives a global energy forecast to the year 2010;[5] and
- The 14th World Energy Conference provides a range of global energy perspectives in the year 2020.[6]

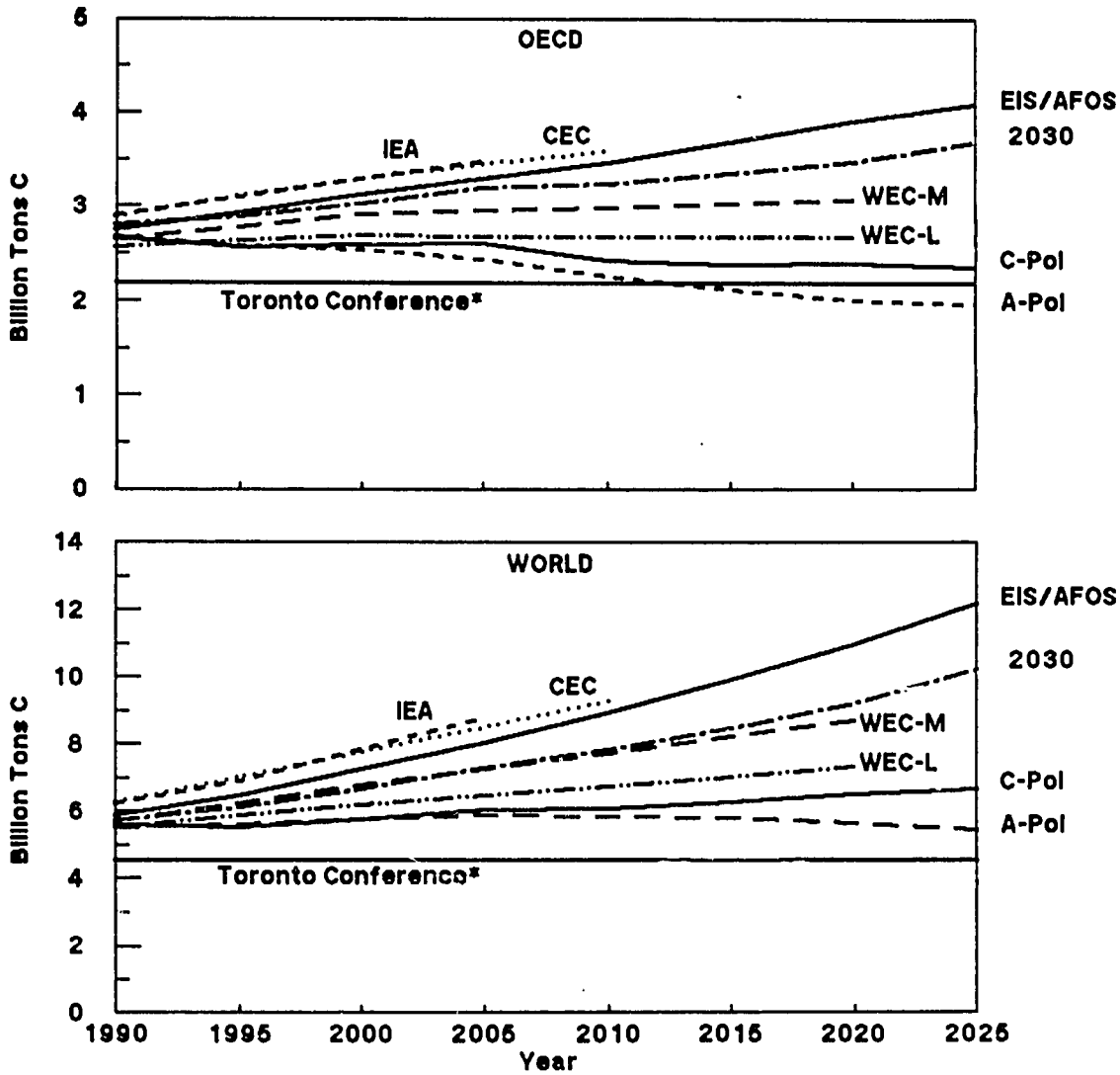
These estimates contain sufficient detail on primary energy supplies to construct CO_2 emission estimates. The same emission coefficients that were used in interpolating and/or extrapolating CO_2 emission results in the IPCC scenarios were applied to energy consumption estimates for the OECD as well as global totals. In order to conform to the IPCC scenarios, only commercial energy use was accounted for, e.g., traditional biofuels were excluded from the calculations. The results are displayed on Figure 3-1 and Table 3-6. Both the IEA and CEC emission estimates are higher than the EIS/AFOS Reference case, although the differences are minor. The calculated emissions under both WEC scenarios remain below those of the EIS/AFOS Reference case. The emissions in the EIS/AFOS Reference case exceed all of the Task A emission scenarios.

The findings of these studies tend to reinforce each other, especially when accounting for the fact that emission estimates tend to diverge as forecast horizons lengthen. Absent changes in energy policies, CO_2 emissions from the OECD will continue to rise, albeit slowly, over the next several decades. Emissions growth in the rest of the world will be more rapid, and global CO_2 emissions will continue to cause CO_2 concentrations to increase for the foreseeable future.

FIGURE 3-1

CO2 EMISSION COMPARISON

EIS/AFOS Reference Case vs. Other Emissions Scenarios



U.S./Netherlands Scenarios:	Other Emissions Scenarios:**
EIS/AFOS = EIS/AFOS Reference Case	WEC = World Energy Conference (Moderate and Low Scenarios)
2030 = 2030 Emissions	IEA = International Energy Agency
C-Pol = Control Policies	CEC = Commission of the European Communities
A-Pol = Accelerated Policies	

* Recommended 20% reduction from 1988 levels by 2005

** CO2 emissions coefficients calculated from those found in Marland and Rotty (1984)

Sources: U.S./Japan Expert Group (1990);[3] Task A Report (1990).[4]

TABLE 3-6

COMPARISON OF CO_2 EMISSIONS IN THE EIS/AFOS REFERENCE CASE WITH ALTERNATIVE ENERGY FORECASTS
(billion tons of carbon)

Study/Forecast	1985	1987	1990	1995	2000	2005	2010	2020
EIS/AFOS Reference Case	5.23		5.87	6.48	7.24	8.05	8.92	11.00
International Energy Agency		5.64		6.71		8.52		
Commission of the European Communities	5.35		6.09	6.81	7.53	8.27	9.01	
14th World Energy Conference								
Moderate Scenario (M)	5.02				6.57			8.45
Limited Scenario (L)	5.02				6.01			7.10

Sources: U.S./Japan Expert Group Report (1990);[3] IEA (1989);[2] CEC (1989);[5] WEC (1989).[6]

3.3.2 Emissions from Deforestation

The CO_2 emissions resulting from tropical deforestation for the various IPCC scenarios are summarized in Table 3-7. Deforestation from temperate regions is assumed to be balanced by reforestation.[c] Two rates of tropical deforestation were evaluated for the Task A Report:

- *Rapid Deforestation.* The rate of deforestation is assumed to increase exponentially, based on population growth in each of the three tropical regions (Latin America, Africa, Asia), from 11 million hectares per year (ha/yr) in 1980 to 34 million ha/yr in about 2050, when the available area of forests in Asia is exhausted.[d] The rate of establishment of tree plantations in the tropics is assumed to be zero. These assumptions result in an increase in net carbon emissions from 0.7 Pg C/yr to more than 2 Pg C/yr in about 2050 before the Asian forests are exhausted. Latin American and African forests are exhausted by 2075, reducing emissions drastically. The total net release of carbon between 1980 and 2100 is about 140 Pg C.

[c] The level of CO_2 emissions from deforestation is subject to considerable uncertainty due to differing assumptions concerning the amount of carbon in the above-ground biomass, the use of the land after it is deforested, among other factors. For these scenarios the IPCC used a lower estimate of carbon stored in the biomass. The EIS/AFOS Reference scenario began with 1985 emissions of CO_2 from deforestation at ca. 1.7 Pg C globally; no regional breakout was provided.

[d] 1 hectare = 2.461 acres.

TABLE 3-7

NET CO_2 EMISSIONS FROM TROPICAL DEFORESTATION
(Pg C/year)

REGION	1985	Rapid Deforestation 2000	Rapid Deforestation 2025	Moderate Deforestation 2000	Moderate Deforestation 2025
Latin America	0.35	0.59	0.83	0.47	0.53
Africa	0.17	0.23	0.33	0.18	0.18
Asia	0.21	0.34	0.64	0.24	0.24
TOTAL	0.73	1.16	1.80	0.89	0.96

Source: Task A Report (1990).[4]

- *Moderate Deforestation.* Tropical deforestation increases gradually, reaching 15 million ha/yr by about 2100. The rate of establishment of tree plantations in the tropics again is assumed to be zero. These assumptions result in emissions that total almost the same amount as in the Rapid Deforestation case, although they are spread out over a longer period. Annual emissions are close to 1 Pg C/yr from 2000 to 2100. The total net release of carbon between 1980 and 2100 is about 120 Pg C.

3.3.3 Emissions from CFCs

Table 3-8 summarizes the emissions from the major CFCs for the 2030 Emissions case.

3.3.4 Emissions from Agriculture

Emissions from agricultural activities were developed by the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) based on an IPCC-sponsored workshop held in December 1989 and subsequent discussions. Without a response to climate change, the rates of greenhouse gas emissions per unit of agricultural activity (e.g., CH_4 emissions per hectare of land used for paddy rice cultivation) were assumed to remain constant over time. However, levels of agricultural activities (e.g., total area of land under paddy rice cultivation) changed through time as population and economic growth occurred. The key activity levels are shown by region in Figure 3-2. The specific emission estimates resulting from these assumptions are summarized in Table 3-9.

TABLE 3-8

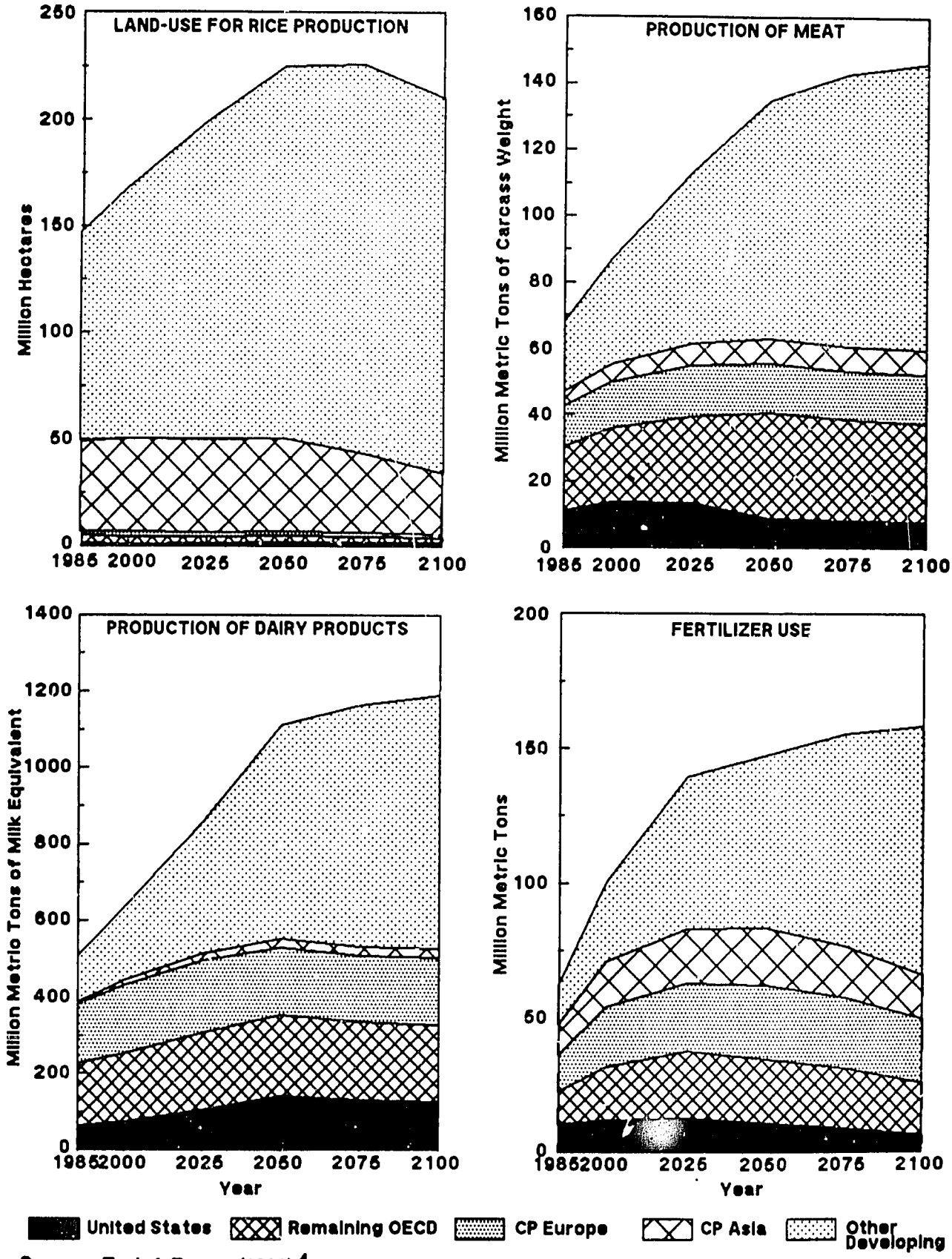
EMISSIONS FROM THE MAJOR CFCS: 2030 EMISSIONS SCENARIO
(10^6 tons)

REGION	CFC-11		CFC-12		HCFC-22		CFC-113		CH_3CCl_3		CCl_4		Halon 1301	
	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025
United States	0.048	0.019	0.108	0.071	0.047	0.421	0.058	0.057	0.394	1.835	0.023	0.013	0.0009	0.0033
OECD Europe/Canada	0.113	0.190	0.091	0.141	0.010	0.140	0.034	0.070	0.180	0.806	0.027	0.036	0.0005	0.0016
OECD Pacific	0.025	0.041	0.032	0.050	0.009	0.037	0.039	0.079	0.049	0.218	0.008	0.010	0.0001	0.0004
Eastern Europe/USSR	0.034	0.078	0.072	0.152	0.004	0.090	0.009	0.029	0.088	0.517	0.014	0.026	0.0002	0.0011
Poland	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Centrally-Planned Asia	0.005	0.024	0.009	0.062	0.001	0.016	0.001	0.016	0.012	0.093	0.002	0.010	<0.0001	0.0001
China	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Middle East	0.003	0.016	0.003	0.022	<0.001	0.008	0.001	0.007	0.001	0.044	0.001	0.004	<0.0001	0.0001
Africa	0.017	0.082	0.016	0.115	0.001	0.039	0.003	0.038	0.029	0.227	0.004	0.023	0.0001	0.0006
Zaire	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Latin America	0.012	0.058	0.011	0.081	0.001	0.028	0.002	0.027	0.020	0.160	0.003	0.016	0.0001	0.0004
Brazil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mexico	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rest of Central America	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
South and East Asia	0.021	0.102	0.022	0.162	0.002	0.052	0.004	0.050	0.038	0.299	0.006	0.030	0.0001	0.0007
India	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indonesia	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pakistan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Philippines	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
World	0.278	0.611	0.364	0.857	0.074	0.831	0.015	0.372	0.813	4.200	0.087	0.168	0.0020	0.0084
World (CO_2-Equivalent Basis; Tg CO_2)	974	2,139	2,655	6,258	111	1,246	632	1,561	81	420	113	219	12	49

Source: Task A Report (1990).[4]

FIGURE 3-2

AGRICULTURAL ACTIVITIES



Source: Task A Report (1990).[4]

TABLE 3-9

EMISSIONS FROM AGRICULTURAL ACTIVITIES: 2030 EMISSIONS SCENARIO

REGION	CH_4 from Rice (Tg) 1985	CH_4 from Rice (Tg) 2025	CH_4 from Animals (Tg) 1985	CH_4 from Animals (Tg) 2025	N_2O from Fertilizer (Tg N) 1985	N_2O from Fertilizer (Tg N) 2025
United States	0.8	1.0	9.8	12.7	0.281	0.343
OECD Europe/Canada	0.7	0.7	14.8	18.9	0.298	0.588
OECD Pacific	1.8	1.3	4.6	8.0	0.024	0.036
Eastern Europe/USSR	1.6	1.8	13.2	16.4	0.311	0.584
Poland	NA	NA	NA	NA	NA	NA
Centrally-Planned Asia	32.1	32.7	6.9	13.3	0.304	0.505
China	26.7	27.2	6.4	12.1	0.282	0.462
Middle East	0.6	0.8	1.0	2.8	0.024	0.060
Africa	2.6	5.5	5.1	13.2	0.054	0.209
Zaire	NA	NA	NA	NA	NA	NA
Latin America	5.9	7.0	9.5	21.0	0.073	0.205
Brazil	4.1	3.7	2.7	4.4	0.017	0.031
Mexico	0.1	0.2	1.1	3.0	0.028	0.101
Rest of Central America	1.6	3.0	2.8	8.4	0.026	0.062
South and East Asia	63.4	97.9	10.1	18.3	0.217	0.938
India	31.1	51.6	5.3	9.0	0.116	0.317
Indonesia	7.3	14.4	0.5	1.1	0.027	0.341
Pakistan	1.2	1.6	1.6	2.9	0.029	0.164
Philippines	NA	NA	NA	NA	NA	NA
World	109.4	148.7	75.2	124.6	1.586	3.468
World (CO_2-Equivalent Basis; Tg CO_2)	2,297	3,123	1,579	2,617	460	1,006

Source: Task A Report (1990).[4]

NOTES AND REFERENCES

1. Zachariah, K.C., and M.T. Vu. 1988. *World Population Projections, 1987-1988 Edition*. World Bank, Johns Hopkins University Press, Baltimore. 440 pp.

2. IEA (International Energy Agency). 1989. *Energy Policies and Programs of IEC Countries, 1988 Review*.

3. For a complete discussion of the methodology used to develop the economic growth estimates, see *An Integrated Analysis of Country Case Studies*. U.S./Japan Expert Group Report to the Energy and Industry. Subgroup of the Intergovernmental Panel on Climate Change, Forthcoming 1990.

4. For a complete discussion, see Task A Report (1990). *Emission Scenarios of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change*, Task A Report of the U.S./Netherlands Expert Group on Emission Scenarios, April 1990.

5. CEC (Commission of the European Communities). 1989. *Major Themes in Energy*, special issue of *Energy in Europe*, September, 1989.

6. WEC (World Energy Conference). 1989. *Global Energy Perspectives 2002-2020*, Conservation and Studies Committee – 14th Congress, Montreal 1989.

CHAPTER 4

BACKGROUND DOCUMENTATION FOR THE ALTERNATIVE APPROACHES TO CONTROLLING GREENHOUSE GAS EMISSIONS WHILE MAINTAINING VIGOROUS ECONOMIC GROWTH

4.1 INTRODUCTION

This chapter provides key background material for the analysis presented in Chapter 4 of the main report, which discussed the potential reductions in emissions that the international community may be able to achieve while maintaining economic growth. The emission estimates were presented in Chapter 4 on a CO_2-equivalent basis; in this chapter emission estimates are expressed in the more conventional units prior to conversion to a CO_2-equivalent basis. The policy scenarios evaluated in Chapter 4 of the main report include three scenarios by the RSWG Expert Group in the Task A Report, including 2060 Emissions, Control Policies, and Accelerated Policies scenarios.[1] In addition to these scenarios, policy studies on several developing countries are included. These individual country studies have been developed by independent experts for the IPCC as potential policy responses for the Energy and Industry Subgroup (EIS) and the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) of the IPCC.[2] As discussed in Chapter 3, EIS/AFOS developed a global Reference case, but they did not develop a complete global policy case. The individual country studies presented here are preliminary and do not reflect official government positions. They are presented to provide additional insight into the potential effect of alternative policy responses.

None of the policy scenarios presented here address the specific actions that would be required to achieve the level of emission reductions assumed, nor do they attempt to estimate the costs of implementing the scenarios. The scenarios have been designed to evaluate what *could* happen if the modified emission levels were achieved.

4.2 EMISSIONS ASSUMING POLICY RESPONSES TO CLIMATE CHANGE

The following sections summarize emissions from the major emission-producing activities.

4.2.1 Emissions From Energy Use

In the policy scenarios, greenhouse gas emissions from energy-related activities are reduced through a combination of energy efficiency measures, a shift to non-fossil energy supplies, and greater reliance on less carbon-intensive fossil fuels (e.g., the substitution of natural gas for coal). For example, in the Task A Report policy scenarios, global primary energy supply increases from about 306 EJ in 1935 to a range of 374 EJ (2060 Emissions/Lower Growth) to 527 EJ (Accelerated Policies/Higher Growth) in 2025 (see Table 4-1). This is compared to a range of 473-737 EJ by 2025 in the non-policy cases. The

overall impact of these changes in energy use patterns on emissions is a significant reduction in global CO_2 emissions compared to the non-policy cases (Table 4-2 and Figure 4-1

TABLE 4-1

GLOBAL PRIMARY ENERGY SUPPLY: POLICY SCENARIOS
(Exajoules/Year)

		2025					
		"2060"		"Control Policies"		"Accelerated Policies"	
	1985	Lower Growth	Higher Growth	Lower Growth	Higher Growth	Lower Growth	Higher Growth
Coal	86	97.8	131.5	105.0	132.8	85.3	101.1
Oil	121	117.0	122.4	117.3	122.4	118.8	117.0
Gas	59	91.6	104.0	81.3	83.4	61.5	59.9
Hydro	19	41.2	48.7	41.1	53.3	43.9	53.4
Other	21	25.9	41.1	29.3	63.9	76.1	194.7
TOTAL	306	373.5	447.7	374.0	455.8	385.6	526.1
Average Annual Growth Rate		0.5	1.0	0.5	1.0	0.6	1.4

Source: Task A Report (1990).[1]

TABLE 4-2

GLOBAL PRIMARY ENERGY CONSUMPTION
(Exajoules/Year)

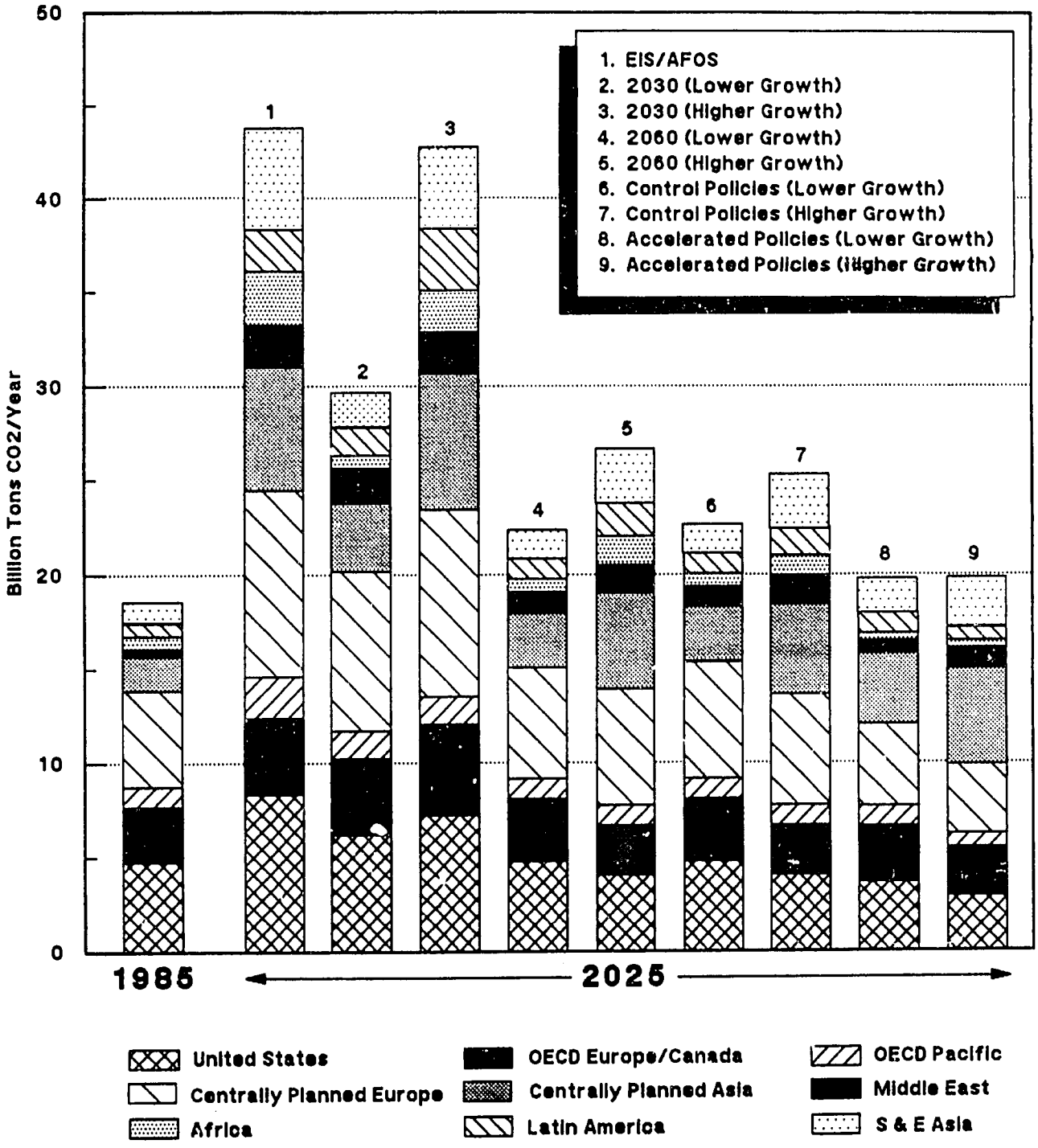
		2025					
		"2060"		"Control Policies"		"Accelerated Policies"	
	1985	Lower Growth	Higher Growth	Lower Growth	Higher Growth	Lower Growth	Higher Growth
United States	77.2	76.0	66.3	76.2	67.9	71.4	71.5
OECD Europe/Canada	62.9	65.1	56.6	65.3	58.0	62.3	62.7
OECD Pacific	19.2	17.1	18.5	16.8	19.3	17.8	19.5
Eastern Europe/USSR	74.9	94.8	99.3	95.3	101.5	84.5	92.4
Centrally Planned Asia	24.5	40.7	65.1	40.5	65.2	53.4	89.6
Middle East	7.7	21.7	26.4	21.6	26.6	11.0	24.0
Africa	8.7	9.8	20.5	9.7	21.2	15.0	33.5
Latin America	15.7	24.6	46.4	24.5	48.0	33.7	65.0
South and East Asia	15.1	24.0	47.5	24.1	48.8	37.2	68.4
TOTAL	305.9	373.8	446.6	374.0	456.5	386.3	526.6

Source: Task A Report (1990).[1]

FIGURE 4-1

CO2 EMISSIONS FROM FOSSIL FUELS BY REGION

(Billion Tons CO2/Year)



Sources: Task A Report (1990);[1] U.S./Japan Expert Group Report (1990).[2]

Key Countries

Table 4-3 summarizes the results of the studies for the key countries. Figure 4-2 shows the changes in CO_2 emissions for the key countries as a result of policy actions.

Table 4-3

SUMMARY RESULTS FROM THE EIS/AFOS CASES FOR KEY COUNTRIES

	Primary Energy Use (EJ/yr)			Average Annual Growth (%/yr)		CO_2 Emissions Annual Emissions (Tg C/yr)			Average Annual Growth (%/yr)	
	1985	2025 Reference	2025 Policy	Reference	Policy	1985	2025 Reference	2025 Policy	Reference	Policy
Brazil	6.0	15.2	9.6	2.7	1.2	41	129	63	2.9	1.1
China	29.0	86.0	73.2	2.8	2.3	503	1,719	1,360	3.0	2.4
India	8.1	36.6	29.0	3.8	3.2	98	620	480	4.0	3.4
Indonesia	1.8	9.3	7.7	4.2	3.7	22	141	111	4.4	3.8
Mexico	4.5	12.0	9.1	2.5	1.8	68	199	133	2.5	1.5
Poland	5.3	11.4	5.7	1.9	0.2	119	255	100	1.9	-0.4

Source: U.S./Japan Expert Group (1990).[2]

4.2.2 Emissions from Deforestation

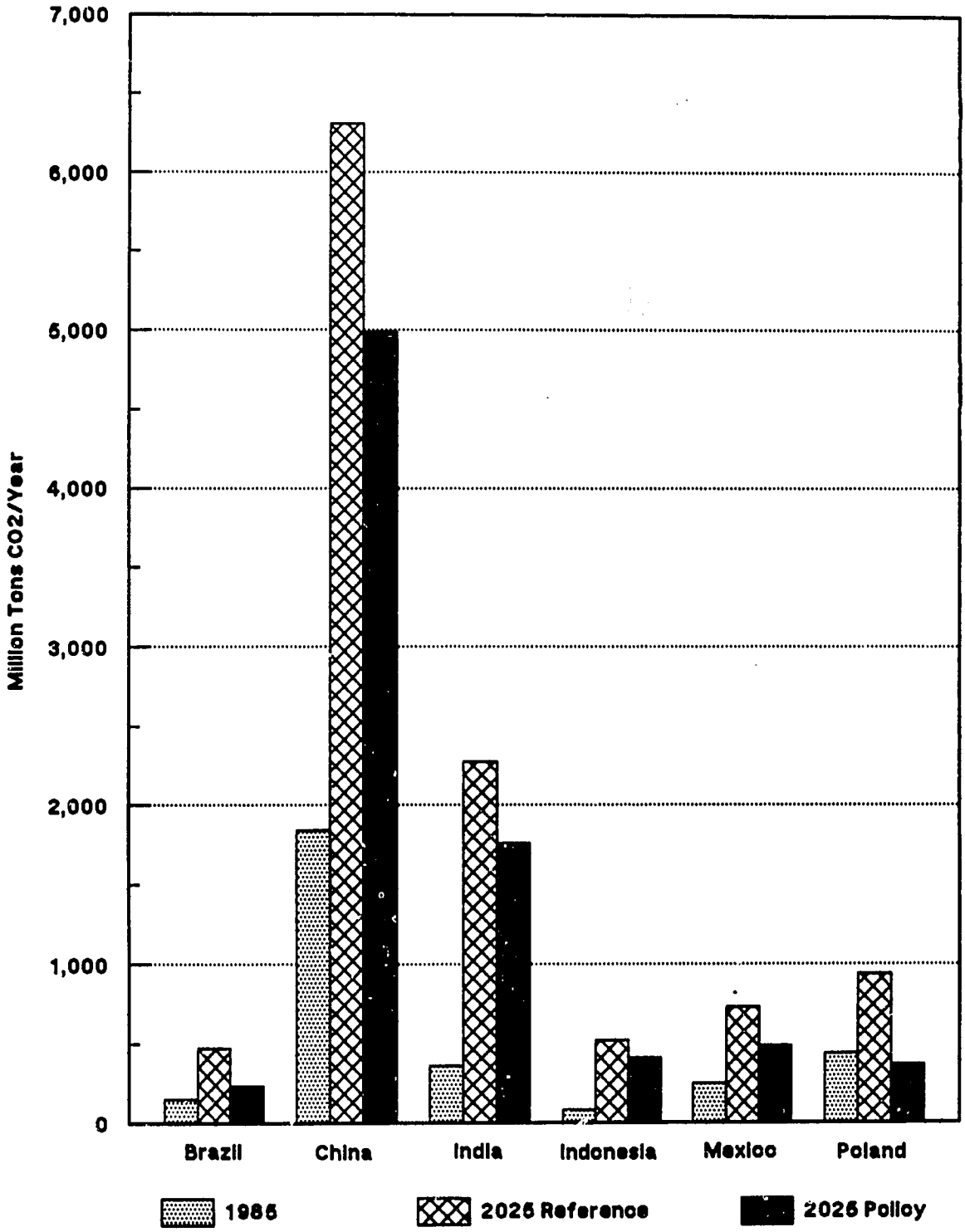
The IPCC evaluated only one scenario that reverses current deforestation trends. Under this scenario, tropical deforestation is assumed to stop by 2025, while about 1 billion hectares (ha) are reforested by 2100.[a] Only land that once supported forests and is not intensively cultivated was assumed to be available for reforestation. Of the reforested land, 380 million ha are assumed to be in plantations; as a result, the remaining land absorbs carbon at a much slower rate but eventually reaches a much higher level of biomass. The biosphere becomes a sink for carbon by 2000 and reaches its peak absorption of 0.7 Pg C/yr before 2025. The size of the sink gradually declines after 2025 as forests reach their maximum size and extent. The reforestation scenario analyzed by the IPCC estimated reforestation for three broad regional levels only -- the tropical areas of Latin America, Africa, and Asia; no further regional breakout was provided. The rates of reforestation are presented in Table 4-4.

[a] The temperate regions of the world are assumed to be in balance, i. e., carbon emissions from deforestation are assumed to equal uptake of carbon from reforestation.

FIGURE 4-2

CARBON DIOXIDE EMISSIONS FROM ENERGY USE IN KEY COUNTRIES

(Million Tons CO2/Year)



Source: U.S./Japan Expert Group Report (1990).[2]

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TABLE 4-4

NET CO_2 EMISSIONS FROM TROPICAL DEFORESTATION (Pg C/year)

REGION	1985	Rapid Deforestation 2000	Rapid Deforestation 2025	Moderate Deforestation 2000	Moderate Deforestation 2025	Reforestation 2000	Reforestation 2025
Latin America	0.35	0.59	0.83	0.47	0.53	-0.26	-0.30
Africa	0.17	0.23	0.33	0.18	0.18	0.01	-0.08
Asia	0.21	0.34	0.64	0.24	0.24	0.02	-0.08
TOTAL	0.73	1.16	1.80	0.89	0.96	-0.22	-0.46

Source: Task A Report (1990).[1]

4.2.3 Emissions from CFCs

Table 4-5 summarizes the emissions from CFC use in the IPCC policy cases. The 2060 Emissions case assumed full compliance with the terms of the Montreal Protocol; the Control Policies and Accelerated Polices cases assumed a phaseout of the major ozone-depleting chemicals.

4.2.4 Emissions from Agriculture

Only the scenarios developed for the Task A Report included an alternative emissions scenario for agricultural activities that assumed policy actions would be taken to reduce agriculture-related emissions. This scenario did not alter the levels of agricultural activity discussed in the previous chapter. The amount of land under paddy rice cultivation, nitrogen fertilizer use, and meat and dairy production were assumed to remain constant. However, technological and management improvements were assumed that lowered the rate of emissions from agricultural activities. For example, methane emissions from domestic animals were assumed to increase at half the rate of herd size between 1985 and 2050 due to productivity increases, changes in meat and dairy production techniques (such as the use of additives like methane-inhibiting ionophores and diet changes), and alterations in animal waste management methods. Methane emissions from rice were assumed to decrease on a per hectare basis by 0.5%/yr as a result of changes in cultivation techniques and cultivars. Emissions per unit of nitrogen applied were assumed to decrease by 0.5%/yr due to changes in types of fertilizers and method of

TABLE 4-5

EMISSIONS OF CFCS AND RELATED CHEMICALS: POLICY SCENARIOS[a]
(10^6 tons)

REGION	CFC-11		CFC-12		HCFC-22		CFC-113		CH_3CCl_3		CCl_4		Halon 1301	
	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025	1985	2025
United States	0.048	0.002-0.039	0.108	0.003-0.063	0.047	0.859-0.995	0.058	0-0.045	0.394	0.321-0.891	0.023	0.029-0.080	0.0009	0.003-3.600
OECD Europe/Canada	0.113	0.004-0.092	0.091	0.003-0.070	0.010	0.188-0.217	0.034	0-0.026	0.180	0.147-0.407	0.027	0.034-0.092	0.0005	0.002-2.000
OECD Pacific	0.025	0.001-0.020	0.032	0.001-0.025	0.009	0.164-0.190	0.039	0-0.030	0.049	0.040-0.111	0.008	0.010-0.026	0.0001	<0.001-0.400
Eastern Europe/USSR	0.034	0.001-0.028	0.072	0.002-0.055	0.004	0.068-0.079	0.009	0-0.007	0.088	0.072-0.199	0.014	0.018-0.049	0.0002	0.001-0.800
Poland	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Centrally-Planned Asia	0.005	<0.001-0.004	0.009	<0.001-0.007	0.001	0.009-0.011	0.001	0-0.001	0.012	0.010-0.026	0.002	0.002-0.006	<0.0001	<0.001-0.065
China	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Middle East	0.003	<0.001-0.003	0.003	<0.001-0.002	<0.001	0.004-0.005	0.001	0-<0.001	0.001	0.005-0.013	0.001	0.001-0.003	<0.0001	<0.001-0.073
Africa	0.017	0.001-0.014	0.016	<0.001-0.012	0.001	0.022-0.026	0.003	0-0.002	0.029	0.023-0.065	0.004	0.005-0.015	0.0001	<0.001-0.372
Zaire	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Latin America	0.012	0.001-0.010	0.011	<0.001-0.009	0.001	0.016-0.018	0.002	0-0.002	0.020	0.016-0.046	0.003	0.004-0.010	0.0001	<0.001-0.263
Brazil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mexico	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rest of Central America	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
South and East Asia	0.021	0.01-0.017	0.022	0.001-0.017	0.002	0.029-0.034	0.004	0-0.003	0.038	0.031-0.085	0.006	0.007-0.020	0.0001	<0.001-0.427
India	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indonesia	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pakistan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Philippines	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
World	0.278	0.011-0.227	0.364	0.010-0.279	0.074	1.357-1.572	0.015	0-0.117	0.813	0.664-1.841	0.087	0.110-0.300	0.0020	0.007-8.000
World (CO_2-Equivalent Basis; Tg CO_2)	974	37-793	2,655	74-2,037	111	2,036-2,358	632	0-490	81	66-184	113	143-390	12	42-46,400

[a] The ranges indicated for 2025 reflect the estimated differences between full compliance with the Montreal Protocol and a complete phaseout of the major CFCs.

Source: Task A Report (1990).[1]

application. (It is possible that policies could also encourage the development of fertilizers that would alter the total quantity of fertilizer required; however, this possibility was not evaluated by the IPCC.) Table 4-6 summarizes the impact of these policies on emissions from agricultural activities.

TABLE 4-6

EMISSIONS FROM AGRICULTURAL ACTIVITIES: TASK A REPORT

REGION	CH_4 from Rice (Tg)			CH_4 from Animals (Tg)			N_2O from Fertilizer (Tg N)		
	1985	2025 Reference	2025 Policy	1985	2025 Reference	2025 Policy	1985	2025 Reference	2025 Policy
United States	0.8	1.0	0.9	9.8	12.7	10.3	0.281	0.343	0.[illegible]35
OECD Europe/Canada	0.7	0.7	0.6	14.8	18.9	15.7	0.298	0.588	0.482
OECD Pacific	1.8	1.3	1.1	4.6	8.0	6.5	0.024	0.036	0.029
Eastern Europe/USSR	1.6	1.8	1.5	13.2	16.4	13.4	0.311	0.584	0.478
Poland	NA	NA	NA	NA	NA	NA	NA	NA	NA
Centrally-Planned Asia	32.1	32.7	26.7	6.9	13.3	11.2	0.304	0.505	0.413
China	26.7	27.2	22.2	6.4	12.1	10.2	0.262	0.462	0.378
Middle East	0.6	0.8	0.6	1.0	2.8	2.3	0.024	0.060	0.049
Africa	2.6	5.5	4.5	5.1	13.2	11.0	0.054	0.209	0.171
Zaire	NA	NA	NA	NA	NA	NA	NA	NA	NA
Latin America	5.9	7.0	5.7	9.5	21.0	17.3	0.073	0.205	0.168
Brazil	4.1	3.7	3.0	2.7	4.4	3.6	0.017	0.031	0.025
Mexico	0.1	0.2	0.1	1.1	3.0	2.5	0.028	0.101	0.083
Rest of Central America	1.6	3.0	2.5	2.8	8.4	6.9	0.026	0.062	0.051
South and East Asia	63.4	97.9	80.1	10.1	18.3	16.0	0.217	0.938	0.767
India	31.1	51.6	42.2	5.3	9.0	8.0	0.116	0.317	0.260
Indonesia	7.3	14.4	11.7	0.5	1.1	0.9	0.027	0.341	0.279
Pakistan	1.2	1.6	1.3	1.6	2.9	2.5	0.029	0.164	0.034
Philippines	NA	NA	NA	NA	NA	NA	NA	NA	NA
World	109.4	148.7	121.6	75.2	124.6	103.7	1.586	3.468	2.822
World (CO_2-Equivalent Basis; Tg CO_2)	2,297	3,123	2,554	1,579	2,617	2,178	460	1,006	818

Source: Task A Report (1990).[1]

NOTES AND REFERENCES

1. Task A Report. 7-8 April 1990. *Emissions Scenarios of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change*. Report and Appendix (2 volumes) of the U.S.-Netherlands Expert Group on Emissions Scenarios.

2. U.S./Japan Expert Group. Forthcoming 1990. *An Integrated Analysis of Country Case Studies*, Report of the U.S./Japan Expert Group to the Energy and Industry Subgroup.

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