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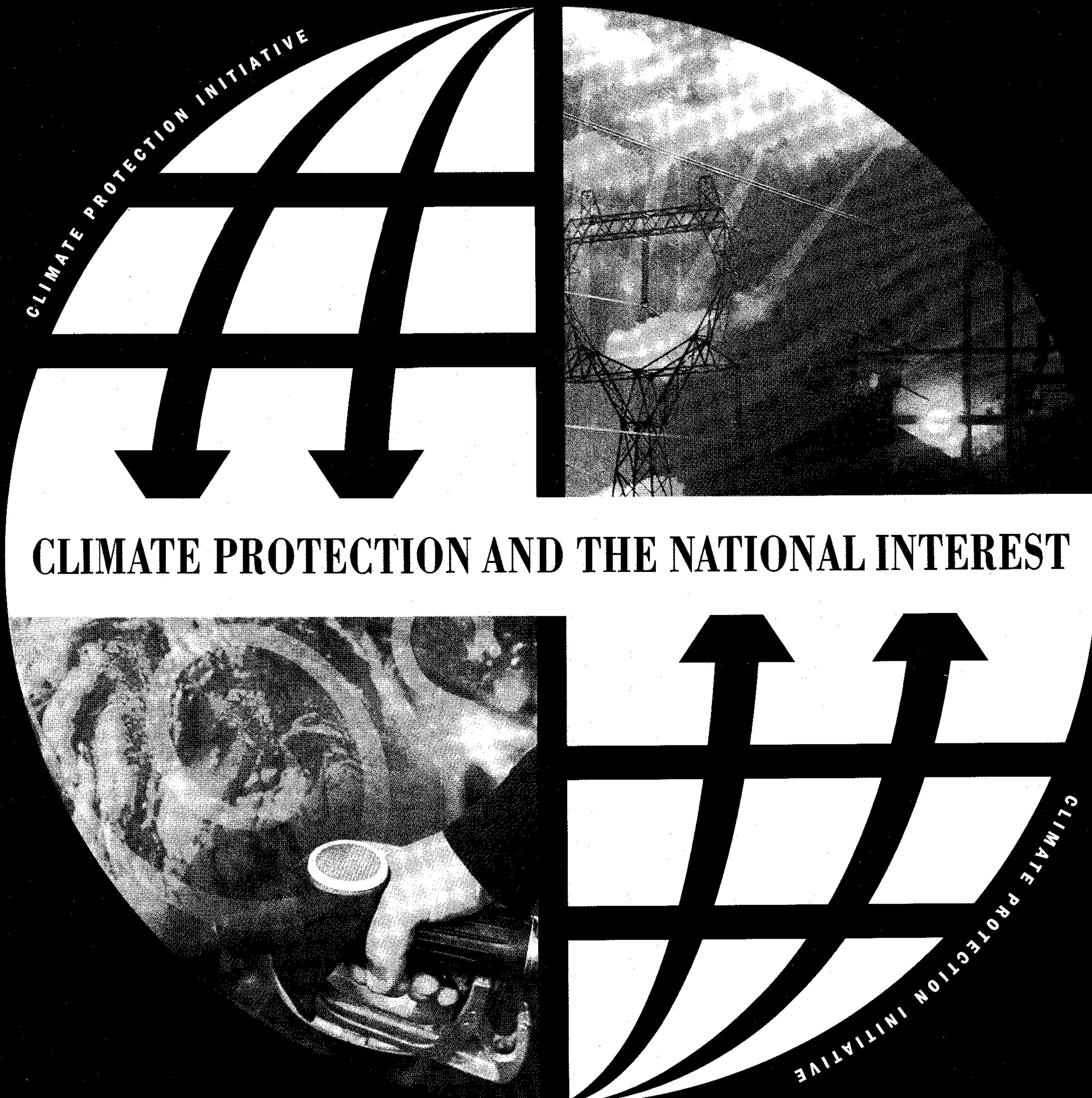

CLIMATE PROTECTION AND THE NATIONAL INTEREST

JAMES J. MACKENZIE

WORLD RESOURCES INSTITUTE

CLIMATE PROTECTION AND THE NATIONAL INTEREST:

THE LINKS AMONG CLIMATE CHANGE, AIR POLLUTION, AND ENERGY SECURITY

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JJM

FOREWORD

Five years after the United States signed the Framework Convention on Climate Change, little progress has been made in limiting U.S. greenhouse gas emissions. A major reason for this inaction is the belief—erroneous, we think—that the costs of reducing emissions, especially carbon dioxide emissions, will be large and immediate, while the benefits remain distant and uncertain. A new WRI study, *Climate Protection and the National Interest: The Links Among Climate Change, Air Pollution, and Energy Security,* by World Resources Institute Senior Associate James MacKenzie helps sort out the benefits of controlling greenhouse gas emissions, not only in reducing the risks of global warming, but in cutting air pollution and enhancing national security as well.

As the United States prepares for the Climate Summit in Kyoto in December, it should recognize that measures to cope with climate change need not—indeed, should not—be thought of as financial burdens. Rather, they represent major business opportunities to develop and introduce new environmentally friendly energy technologies that will address not only the climate problem but other vexing national problems as well. For example, technologies that combat climate change can also help abate air pollution. And measures to cut carbon emissions from vehicles will enhance national security by cutting oil imports from unstable regions of the world. Climate change, air pollution, energy security. All are interconnected because they are rooted in our consumption of fossil fuels. Policy based on a clear appreciation of this synergy will rely on cost-effective integrated approaches rather than costly stop-gap measures that characterize past, piecemeal approaches to individual environmental problems.

The linkages among these problems provide a useful framework for business leaders and policy-makers to approach long-term corporate and economic planning. In the global effort to reduce greenhouse gas emissions, greater business investment will be needed for more energy-efficient and sustainable technologies. The markets for these technologies will be global and represent enormous opportunities for growth across the U.S. economy. As the world's largest consumer of energy and a leader in cutting-edge environmental technology, the United States can play a key role in this transition from a largely fossil-fuel dependent economy to one based on renewable and more sustainable forms of energy.

The World Resources Institute through its Climate Protection Initiative is reaching out to the business community to form partnerships to identify sound policies and strategies to achieve climate protection goals. This effort is based on the belief that climate protection and a sound economy can co-exist. As *Climate Protection and the National Interest* shows, the links among climate change, air pollution, and energy security lend themselves to creative solutions that will yield important benefits not only for the climate but in other areas as well. But we can only achieve these optimal results if policy-makers and business leaders understand these links.

We at the World Resources Institute hope that *Climate Protection and the National Interest* will help the business community to appreciate the opportunities that will open up as policies evolve to protect Earth's climate. And we hope that this report will be helpful to those searching for sound overall policies to combat these complex and interrelated problems.

We would like to thank the U.S. Environmental Protection Agency, The Summit Foundation, The Nathan Cummings Foundation, and The Charles Stewart Mott Foundation for their support of WRI's Climate Protection Initiative under whose auspices this report was prepared. We also thank The Joyce Foundation, The Rockefeller Brothers Fund, and The Pew Charitable Trust for their support of WRI's work on climate, energy, and pollution issues.

Jonathan Lash
President
World Resources Institute

1 INTRODUCTION

The United States today faces challenging threats related to climate change, air pollution, and energy security. These threats have their roots in our consumption of energy and are linked through the gases, pollutants, and technologies associated with the burning of fossil fuels. If tackled together, these linked problems can be solved far more efficiently and economically than if addressed separately. Yet, the nation continues to treat them separately, sometimes alleviating one only to exacerbate the others. Major decisions that address each problem in isolation are being made every day, and we are missing the opportunities and benefits that could be gained from solving them as a package. It is time to re-think our approach.

> **In order to reduce greenhouse gases and grow the economy, we must invest more in the technologies of the future...With the best ideas and strategies, and new technologies and increased productivity and energy efficiency, we can turn the challenge to our advantage.**
>
> *Pres. Bill Clinton*
> *Remarks to the United Nations*
> *June 26, 1997*

Policy approaches that grasp win-win opportunities can expect broad public support. People seem more willing to pay the price for actions that simultaneously protect Earth's climate, safeguard the health of today's citizens, and enhance national security by minimizing military conflict, than they would be to support actions to achieve each goal separately. Across the board, it is time to look for systemic solutions to vexing policy problems rather than continuing the inefficient and often ineffective approach of treating only the symptoms of those problems.

This report provides the foundation for designing common solutions by explaining how the problems are linked and what technological paths can most readily surmount them. In capsule, the set of linked problems follows:

Climate Change, which could affect virtually every aspect of national life, stems from the build-up in the atmosphere of certain "greenhouse" gases, in particular, carbon dioxide—largely the result of burning fossil fuels. At the 1992 Earth Summit in Rio, 166 countries endorsed the United Nations Framework Convention on Climate Change (UNFCC). International negotiations are now underway among the UNFCC signatories to define a protocol that will limit emissions of greenhouse gases after the year 2000. These negotiations, set to conclude in December 1997, have become politically charged as individual countries weigh the perceived risks to their economies against the future risks of climate change and seek to allocate responsibility in a manner most favorable to their own interests.

Local and Regional Air Pollution threatens human health and the environment. Though alleviated by federal and state programs, air pollution—largely from fuel burning—still poses health risks to one in three Americans. Air pollution directly affects human health and, when transported over long distances, acidifies streams, lakes, and soils and in so doing, harms aquatic life, reduces crop yields, and injures and kills trees. Pollution also impairs visibility and damages buildings and monuments; some air pollutants contribute to climate change. Air quality standards have been the focus of heated debate over the past year, as the U.S. Environmental Protection Agency considered and ultimately adopted strengthened standards to reduce exposures to ozone and small airborne particles. Controversy will no doubt continue for years as cities grapple with the challenge of complying with the new standards.

Growing Dependence on Imported Oil threatens long-term U.S. security. National security is increasingly jeopardized by our growing dependence on imported oil, especially from the unstable Middle East. In 1996, the United States imported (net) more than 46 percent of its oil supply—and twice as much oil from the Persian Gulf as it did in 1973 before the Arab oil embargo. Middle East nations accounted for fully 30 percent of global oil production in 1995, contrasted with only 18 percent in 1985. Dependence on imported oil profoundly influences U.S. foreign policy: The risks to Middle Eastern oil supplies factored heavily in U.S.

involvement in the 1991 Persian Gulf War. Additionally, increased dependence on imports adds pressure to produce oil from environmentally sensitive areas at home. Debates frequently rage over the economic and environmental tradeoffs associated with further exploration for oil in Alaska, or with the development of other energy sources in areas of high value for biological diversity and wilderness protection.

For many energy-related issues, the synergies and trade-offs among these three problems are very much apparent. Consider the restructuring of the electric power industry that is occurring. To increase competition and provide cheaper power to consumers, the United States is deregulating its electric utilities. With this restructuring, consumers will be able to purchase electric power from the supplier of their choice, just as deregulation of the telephone industry gave consumers access to different suppliers of long-distance service. Unfortunately, in many regions the cheapest source of electricity tends to be coal-fired power plants that pose major threats to human health and Earth's climate from their high emissions of air pollutants and carbon dioxide. Without special financial provisions to take into account these environmental and health impacts, electric power deregulation can be expected to decrease demand for clean, renewable (albeit somewhat more expensive) energy sources such as photovoltaic cells and windpower. This could diminish investment in these power sources and slow the technological advances that would bring prices down. If this happens, the development of affordable, climate-friendly renewable energy substitutes for fossil fuels could be slowed down for years. Whether or not lower energy prices resulting from restructuring are economically justified given the likely impacts on climate and air pollution, the environmental issues have barely entered the policy debate.

The time to consider the policy dimensions of climate change is not when the link between greenhouse gases and climate change is conclusively proven... but when the possibility cannot be discounted and is taken seriously by the society of which we are part. We in BP have reached that point.

John Browne, CEO, British Petroleum
at Stanford University
May 19, 1997

As another example, consider the potential multiple benefits if the United States were to take strong steps to reduce carbon dioxide emissions—through improved energy efficiency or fuel substitution, for example. Many such measures would also tend to reduce emissions of air pollutants such as sulfur dioxide and nitrogen oxides. Preliminary estimates are that they could be significant. The UN's Intergovernmental Panel on Climate Change (IPCC) estimates that benefits, such as reduced air pollution, could offset between 30 and 100 percent of climate abatement costs.[1] In other words, actions to reduce U.S. greenhouse gas emissions to protect the climate could also substantially aid our efforts to achieve air quality and other national goals. Yet, few of the economic models being used to examine climate protection policies have factored in the associated economic, health, and environmental benefits of reduced air pollution.[2] Similarly, cutting oil consumption through strong climate policies would help reduce energy security risks. But, here too, economic models do not estimate these reductions nor the potential averted economic and human costs of military conflicts in the Persian Gulf.

Clearly, there are win-win opportunities that are being ignored in the struggles to deal with these closely linked threats. In the following pages, as we explore these energy-related issues in more detail, it will become clear how and why these problems are interrelated, why there are benefits in addressing them as a package, and what kinds of technological and policy goals are appropriate to guide national decision-makers in resolving them.

2 THE CLIMATE CHANGE PROBLEM

There is no doubt that Earth has a natural greenhouse effect. Without it, the world would be about 33°C (60°F) colder. Life as we know it would not be possible. The great French physicist Jean Fourier argued 170 years ago that Earth's atmosphere acts like the glass of a greenhouse by admitting the sun's light while impeding the escape of the earth's radiant heat (infrared radiation) back into space.

In 1896—after performing at least 10,000 hand calculations—the Nobel-prize winning Swedish chemist Svante Arrhenius correctly reasoned that the quantities of water vapor and carbon dioxide (CO_2) in the atmosphere absorb enough of the earth's outgoing heat radiation to warm the earth by nearly 33°C (60°F). Arrhenius concluded that a doubling of atmospheric CO_2 would raise average global temperatures by 5 to 6°C (9 to 11°F) over the preindustrial temperature.[3] This is remarkably close to the range of 1.5 to 4.5°C (2.7 to 8.1°F) that climate experts now believe would accompany a doubling of atmospheric CO_2.[4]

Over the past century, human agricultural and industrial activities have led to the buildup of CO_2 and other greenhouse gases, including methane, nitrous oxide, ozone, and the halogenated compounds (including the CFCs). These gases are trapping yet more of the earth's outgoing radiation, leading to an enhanced greenhouse effect and, eventually, to a warmer earth. (*See the sidebars* on pages 5–7 for a discussion of the sources, properties, and emission trends of the important greenhouse gases.)

CARBON DIOXIDE

The buildup of carbon dioxide accounts for about two-thirds of the human sources of excess greenhouse warming from long-lived gases.[5] (Figure 1 shows the history of global CO_2 emissions.) Each year, the burning of fossil fuels and biomass, along with other activities such as cement making, releases over seven billion metric tons of carbon to the atmosphere in the form of CO_2, raising the atmospheric concentration of the gas by about half a percent annually. Figure 2 shows CO_2 emissions for the United States for the period 1980 to 1996 while Figure 3 shows the source of emissions for 1994 by sector and fuel. Note that electric-power production and transportation are by far the largest and fastest-growing sources. With current global emissions of some 6.3 billion metric tons per year (1995), fossil fuel combustion is the best quantified and the largest source of CO_2 from human activity. Since preindustrial times, the global CO_2 concentration has increased almost 30 percent, from 280 parts per million (ppm) to about 360 ppm today. (*See Figure 4.*) Carbon dioxide stays in the atmosphere 50 to 200 years.[6]

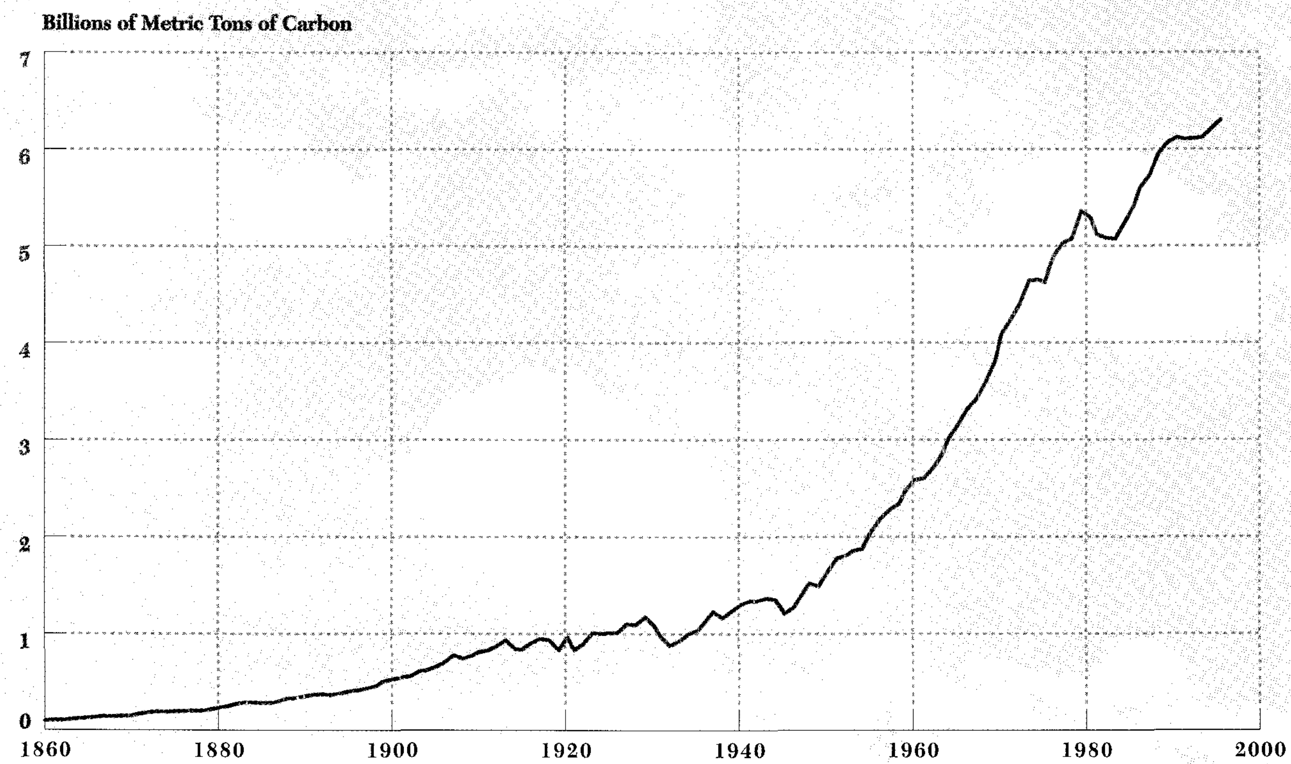
METHANE

Methane (the main component of natural gas) has both natural and human sources. Natural sources include peat bogs, termites, swamps, and other wetlands. Human sources include rice paddies, domestic animals, landfills, biomass burning, and the production and burning of fossil fuels. Fossil fuels account for about 20 percent of the total, including leakage from natural gas pipelines, oil wells, and coal seams.[7] About 60 to 80 percent of all methane emissions are of human origin. Atmospheric methane concentrations have been increasing in the atmosphere at about 0.6 percent per year[8] and have more than doubled from preindustrial levels. Methane stays in the atmosphere 12 to 17 years and accounts for about 20 percent of greenhouse warming from human sources.

THE COOLING EFFECT OF AIR POLLUTION

In addition to the CFC destruction of ozone (*see the sidebar* on halogenated compounds), a second cooling effect offsets some global warming. Small atmospheric particles (called aerosols) are formed from sulfur dioxide air pollution, biomass burning, and other sources. These aerosols

FIG. 1 GLOBAL CARBON DIOXIDE EMISSIONS FROM FOSSIL FUELS



NITROUS OXIDE (N_2O)
The principal sources of nitrous oxide from human activities are the application of nitrogen fertilizers to agricultural lands, the burning of biomass and fuels, and industrial chemical production. Human sources are about a third of total global emissions. Nitrous oxide is a very stable molecule (lifetime of 120 years) and also contributes to stratospheric ozone depletion.[9] This gas accounts for about 5 percent of the human sources of greenhouse warming.

shield the earth—mostly in regions down-wind of industrialized areas—from some of the incoming sunlight and cause cooling both directly, by scattering sunlight, and indirectly, by helping to form reflective clouds.[13] According to the Intergovernmental Panel on Climate Change (IPCC), these small particles have offset some of the expected global warming over the past several decades. The predicted warming, with and without the aerosol effect, is shown in Figure 5. The cooling effect of the aerosols brings the calculated rise in temperature into closer agreement with the observed changes of the past few decades. Unlike most greenhouse gases, aerosols remain in the air for only a matter of days. As a result, as pollu-

BOX 1 THE 12 HOTTEST YEARS IN RECORDED HISTORY (In descending order)

1995, 1990, 1991, 1981, 1996, 1988, 1987, 1994, 1983, 1980, 1989, 1993

Source: Goddard Institute for Space Studies, NASA.

BOX 2 THE CLIMATE CONVENTION

The problem of climate change is being addressed internationally through the UN Framework Convention on Climate Change (UNFCCC). Important milestones include

1992 166 governments endorse the UNFCCC at the Earth Summit in Rio de Janeiro. The United States ratifies the treaty on October 15, 1992.

1993 By November, 50 nations have ratified the treaty.

1994 UNFCCC enters into force in March.

1995 First meeting of the Conference of the Parties (COP1), in Berlin. "Berlin Mandate" adopted to guide negotiations of a protocol requiring further action for post-2000.

1996 At COP2, in Geneva, United States takes strong position in favor of binding targets and timetables for reducing emissions.

1997 COP3 in Kyoto in December. The goal is to adopt a protocol that will required reductions in greenhouse gas emissions after the year 2000.

tion emissions are reduced, so too will the cooling effect of the aerosols. Given the continued need to cut air pollution emissions to protect health and reduce acid deposition, the task of cutting greenhouse gas emissions becomes increasingly important.

SEARCHING FOR THE SIGNAL OF GLOBAL WARMING

Global surface-temperature data indicate that over the past century the earth has warmed by about 1°F (about 0.5°C). Although there is no doubt that greenhouse gases are building up in the atmosphere, there is less certainty about whether the bulk of the observed warming over the past century is a direct result of this buildup or partly the result of a natural fluctuation. Much of the warming has occurred recently: 1995 was the hottest year in the past century, and the next 11 hottest years have all occurred since 1980. *(See Box 1.)* According to the 1995 IPCC assessment, "the observed warming trend is unlikely to be entirely natural in origin," and "the balance of evidence suggests that there is a discernible human influence on global climate."

Global surface-temperature data indicate that over the past century Earth has warmed by about 1°F. Much of the warming has occurred recently: 1995 was the hottest year in the past century and the next 11 hottest years have all occurred since 1980.

HALOGENATED COMPOUNDS

Halogenated compounds contain fluorine, chlorine, bromine, or iodine, and many such compounds are strong greenhouse gases. Halocarbons containing carbon and either chlorine or bromine, such as the CFCs, halons, and HCFCs, also cause stratospheric ozone depletion. CFCs are made for use as aerosol propellants, blowing agents for plastic foams, refrigerants, and solvents. They are particularly damaging as greenhouse gases because of their long lives in the atmosphere and their effectiveness in trapping heat, approximately 20,000–30,000 times that of CO_2. Hydrofluorocarbons (HFCs)—substitutes for some CFC applications—are also potent greenhouse gases.

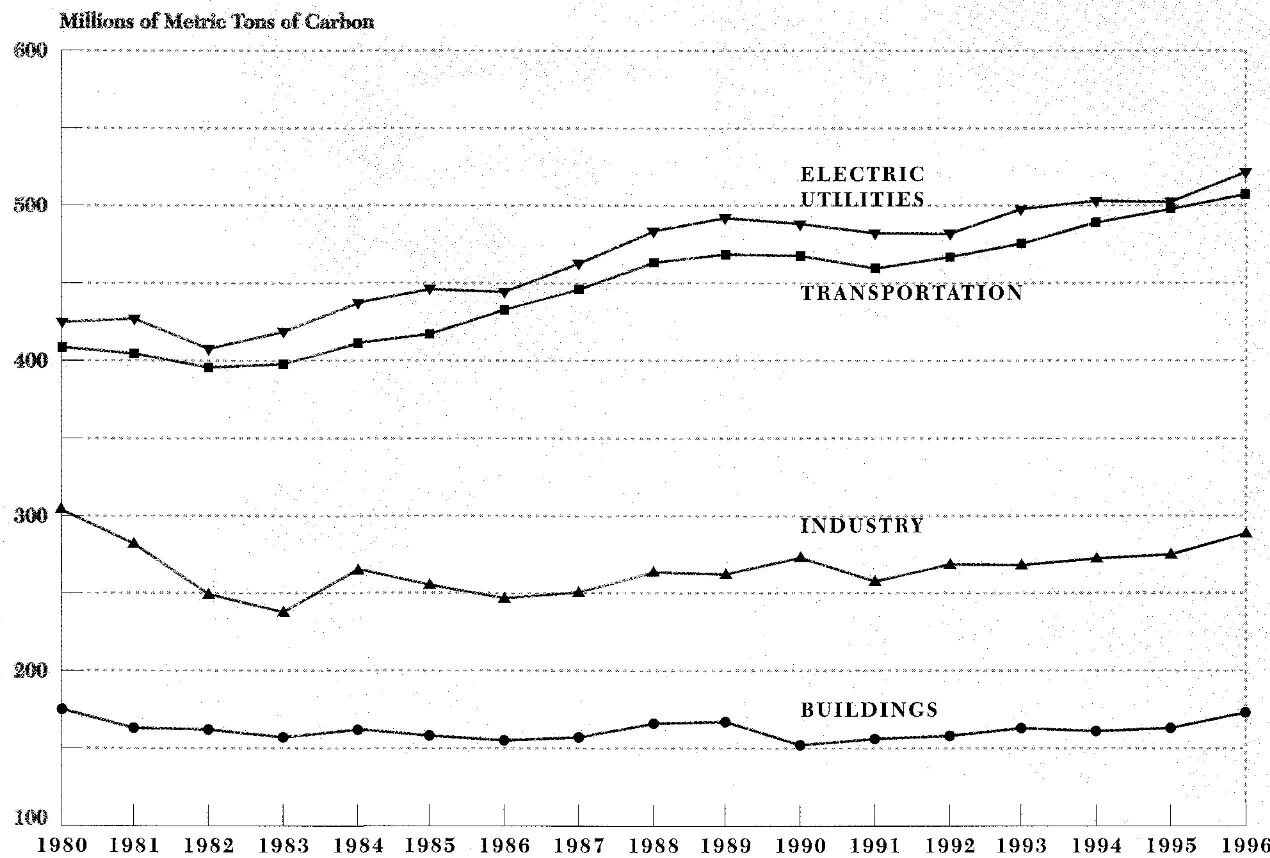
Estimates of the net warming effect of CFCs have recently been reduced. This reduction stems from the cooling effect from the CFC destruction of ozone (a greenhouse gas) in the lower stratosphere.[11] CFCs and some other ozone-depleting compounds have been phased out in the industrialized countries by the Montreal Protocol on Substances that Deplete the Ozone Layer but production for essential uses and to meet developing-country needs continues.

Also included in the halocarbon family are perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6), which have lifetimes measured in thousands of years. PFCs are a byproduct of aluminum making and are also manufactured for use in the semiconductor industry. They are exceedingly powerful greenhouse gases. Though presently low, concentrations of the PFCs and SF_6 are increasing. Because of their long lifetimes, these compounds represent an essentially irreversible threat to the climate.[12] The halocarbons contribute about 10 percent of the warming from human sources.

OZONE IN THE LOWER ATMOSPHERE

Ozone (O_3) in the upper atmosphere (stratosphere) acts as a crucial filter that protects life on the planet from many of the harmful effects of ultraviolet radiation. However, ozone in the lower atmosphere (troposphere) is both a greenhouse gas and, in many polluted urban areas, a threat to public health. Nitrogen oxides (NO_x) and volatile organic compounds (VOCs) are both necessary for ozone formation. VOCs and NO_x have both natural as well as man-made sources, but in urban areas, which are prone to ozone formation, combustion is a major source of both.[10] As NO_x are formed, they combine with VOCs in the presence of sunlight to form tropospheric ozone. Background tropospheric ozone concentrations, the evidence suggests, have approximately doubled in the northern hemisphere since preindustrial times.

FIG. 2 TRENDS IN U.S. CO_2 EMISSIONS

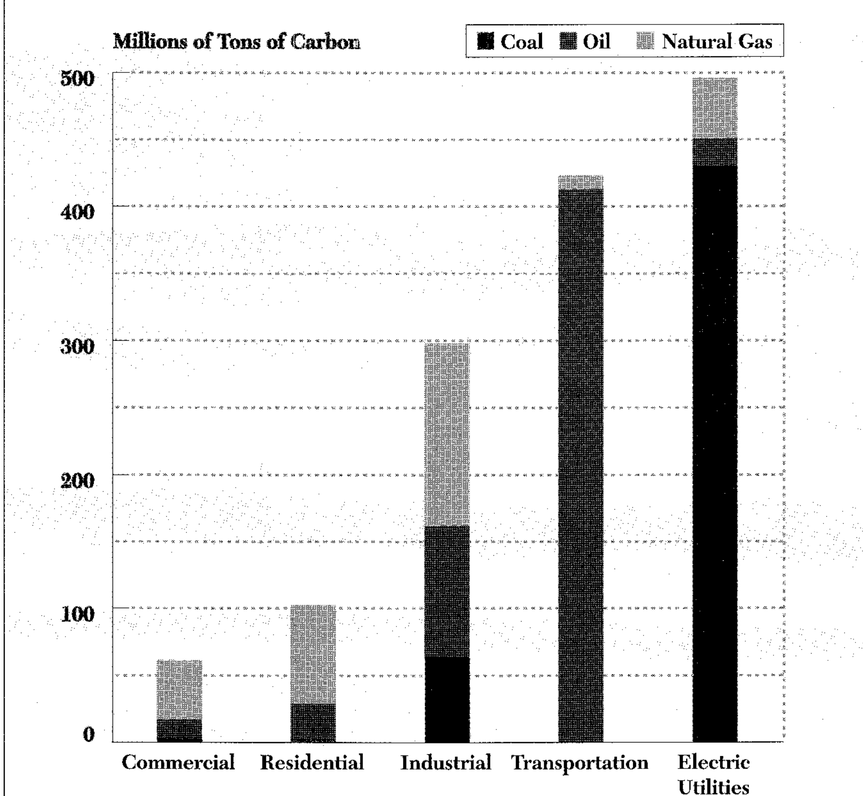


Although the basic principles of enhanced greenhouse warming are scientifically well established, there are still significant uncertainties about the size of regional changes, when they will appear, and what their consequences will be. Climatologists study climate change using complex computer models. When incorporated into these models, the two cooling effects just described—the CFC-ozone connection and the pollution-aerosol effect—go a long way toward explaining why the observed warming over the past few decades is lower than climatologists had predicted based solely on the buildup of greenhouse gases.

The threat of climate change is being addressed through the United Nations Framework Convention on Climate Change, which was adopted at the Earth Summit in 1992. Countries worldwide will meet in December 1997 in Kyoto with the goal of adopting a protocol to reduce greenhouse gas emissions. Important milestones in the treaty process are listed in Box 2.

Many recent studies provide supporting evidence for the IPCC's 1995 conclusion that human-induced warming of the earth is probably occurring. Combining data on droughts, above-normal precipitation in the winter months, drenching rainstorms, and other weather extremes, Thomas Karl and his colleagues at the National Climatic Data Center in Asheville, North Carolina, constructed a Greenhouse Climate Response Index for the United States. Since 1980, the index has been elevated, indicating an above-average number of extreme events. Karl and his colleagues believe there is only a 5 to 10 percent chance that this is a natural fluctuation.[14] According to Karl, the trends are indeed those projected for an intensified greenhouse.[15] In a warmer world, he says, there will be more precipitation, and it will be more likely to come in more extreme events.[16]

FIG. 3 U.S. CARBON DIOXIDE EMISSIONS BY FUEL AND SECTOR (1994)



The conclusion that the observed warming trend is not simply a natural fluctuation is affirmed by research at several institutions. Basing their conclusions on climate model calculations, scientists at the Max Planck Institute for Meteorology in Hamburg, Germany, concluded that the warming of the earth over the past 30 years goes far beyond natural variations, indeed has only one chance in 40 of being natural.[17]

Several other elements of a "global warming fingerprint" have been observed. Primarily as a result of ocean warming and the

FIG. 4 GLOBAL CO_2 CONCENTRATION

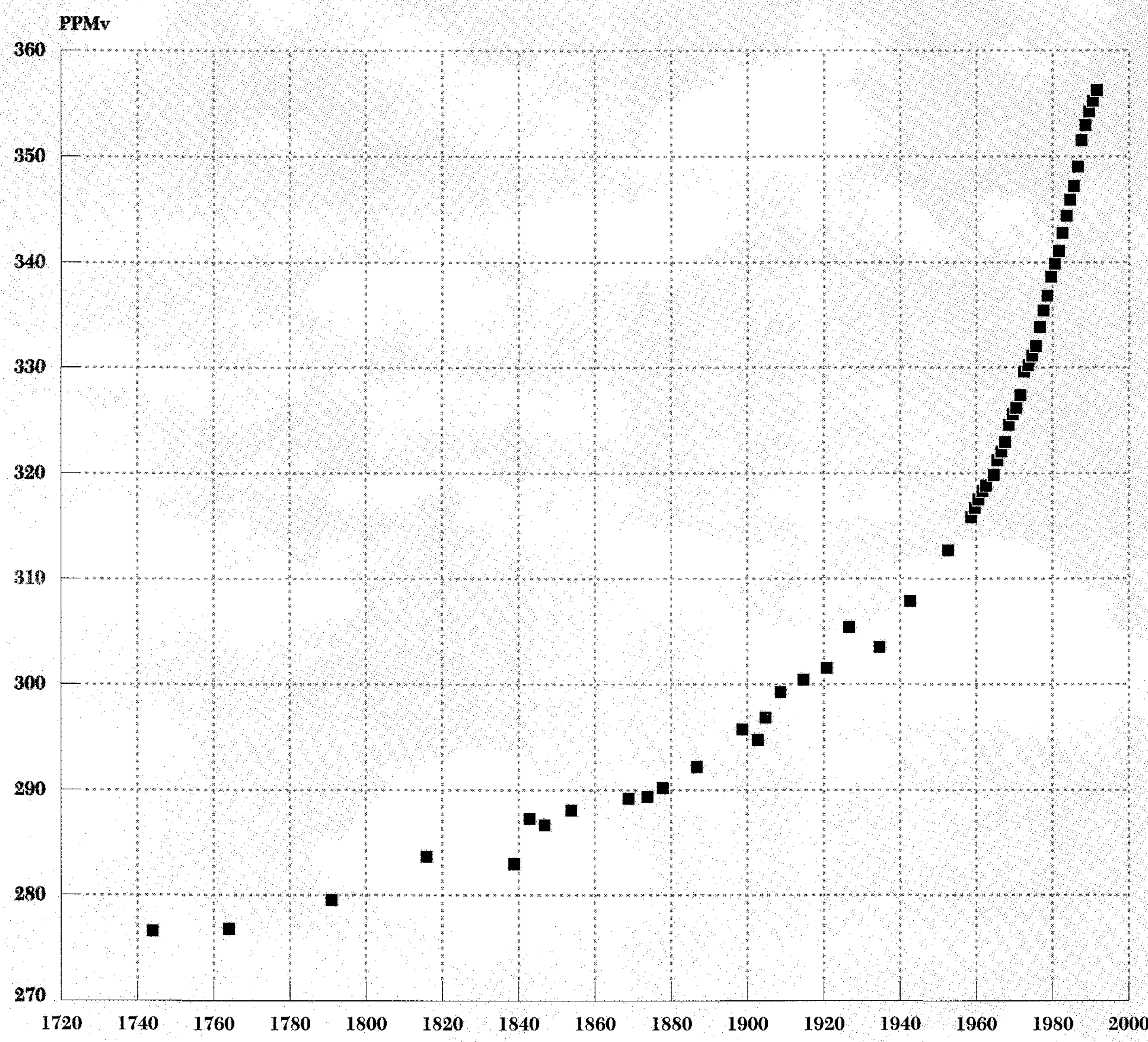
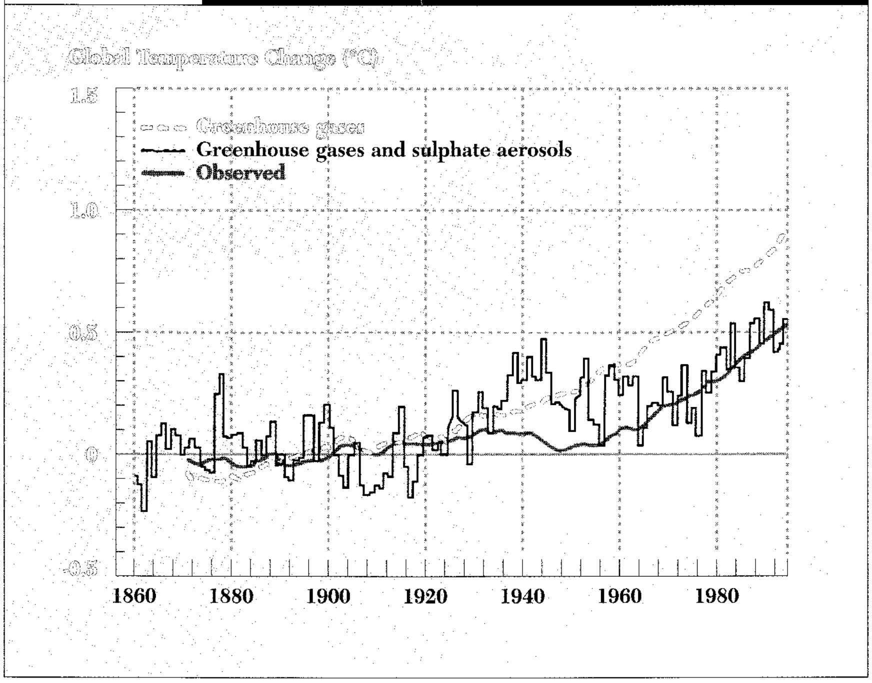


FIG. 5 EFFECT OF AEROSOLS ON TEMPERATURE



melting of glaciers, sea levels are rising slightly more than 2 mm per year (about 1/16 of an inch). They have already risen by 10 to 25 cm (4 to 10 inches) over the past century.[18] Climate change, including sea-level rise and a more intense hydrological cycle, will increase the vulnerability of some coastal populations to flooding and erosional land loss.[19] Already, some 46 million people are at risk of flooding due to storm surges.

Sea ice around Antarctica is melting, and the Arctic ice pack has been shrinking faster during the past two decades.[20] Studies by Norwegian scientists show that Antarctic sea ice is declining by 1.4 percent per decade.[21] The temperature at the South Pole has increased by 2.5°C (4.5°F) over the past 50 years.[22] At the North Pole, sea-ice melting has accelerated from 2.5 percent per decade to 4.3 percent.[23]

Glaciers continue to retreat. According to recent work at the University of Colorado's Institute of Arctic and Alpine Research, the world's total glacier mass has diminished by about 12 percent over the past 100 years as a result of higher temperatures.[24] A separate Russian study also shows that the volume of small glaciers has decreased. Australian scientists have reported that the equatorial glaciers on the summit of Mt. Jaya in Indonesia are disappearing rapidly, most likely from Earth's warming.

EXPECTED IMPACTS OF GLOBAL WARMING

Because CO_2 and other greenhouse gases are so long-lived in the atmosphere, enhanced greenhouse warming can be expected to persist for centuries. The impacts—many of which are effectively irreversible[25]—will affect everyone on earth. Human health, patterns and intensity of precipitation, water and food supplies, coastal development, energy supplies, the viability of natural systems: all will be affected if Earth's climate continues to change.

Several kinds of health impacts from higher temperatures have been identified, both direct and indirect. The long term will see the predominance of indirect effects, including the spread of vector-borne infectious diseases.[26] Several such diseases, including malaria, dengue, and viral encephalitides, are particularly sensitive to changes in climate. The symptoms of dengue, a disease spread by mosquitos, include fever, headaches, and joint and muscle pain. Its severe form causes widespread hemorrhaging. The disease is spreading north through Mexico and has been recently detected in Texas. In the past 20 years there has been a dramatic increase in dengue and dengue hemorrhagic fever worldwide with 50 to 100 million cases of dengue a year, and several hundred thousand cases in its severe hemorrhagic form. Two species of mosquito capable of spreading the disease have already entered the United States and fanned out across the lower Southeast.

The 1993 outbreak of hantavirus pulmonary syndrome—a sudden respiratory disease that killed 53 percent of the people it struck—provides a dramatic example of how a subtle climate change, even a temporary one, can promote disease.

The 1993 outbreak in the Southwestern United States of hantavirus pulmonary syndrome, a sudden respiratory disease, killed 53 percent of the people it struck. It provides a dramatic example of how a subtle climate change, even a temporary one, can promote disease.[27] The outbreak was traced to a 10-fold increase in the population of deer mice that carry the virus. This increase resulted from six years of drought (which reduced the population of mouse predators) followed by heavy rains in the spring of 1993 (and an abundance of food for the mice). The mice shed the virus in their urine, and contaminated dust spread the disease widely.

More directly, the frequency of heat-related illness and death is expected to increase. Extreme heat waves can bring on heart attacks, strokes, or other fatal ailments in people at risk. Using models that estimate climate change for the year 2020 and 2050, researchers estimate that summer mortality will increase dramatically and winter mortality will decrease slightly.[28] (Researchers estimate that perhaps 40 percent of those dying from heat waves would have died soon regardless of the weather.) Other direct health effects include deaths and injury from more extreme weather events (floods, storms, winds).[29] Additional warming in urban areas would accelerate the formation of air pollutants such as smog (largely ozone), with negative consequences for human health. In sum, a sizable net increase in weather-related human mortality is expected if the climate warms as the models predict.[30]

Changing precipitation patterns can also lead to major social upheaval. The disastrous 1996–97 winter and spring floods in various regions of the United States illustrate what could lie ahead. The National Oceanic and Atmospheric Administration (NOAA) expects extreme flooding like the December 1996–January 1997 floods in the Northwest to become more frequent across the country due to an increase in precipitation extremes caused by climate change.[31] These storms led to 30 deaths, to the evacuation of more than half a million people, and to property losses exceeding several billion dollars (including $1.8 billion in California, $500 million in Nevada, and $125 million of insured losses in Washington state).

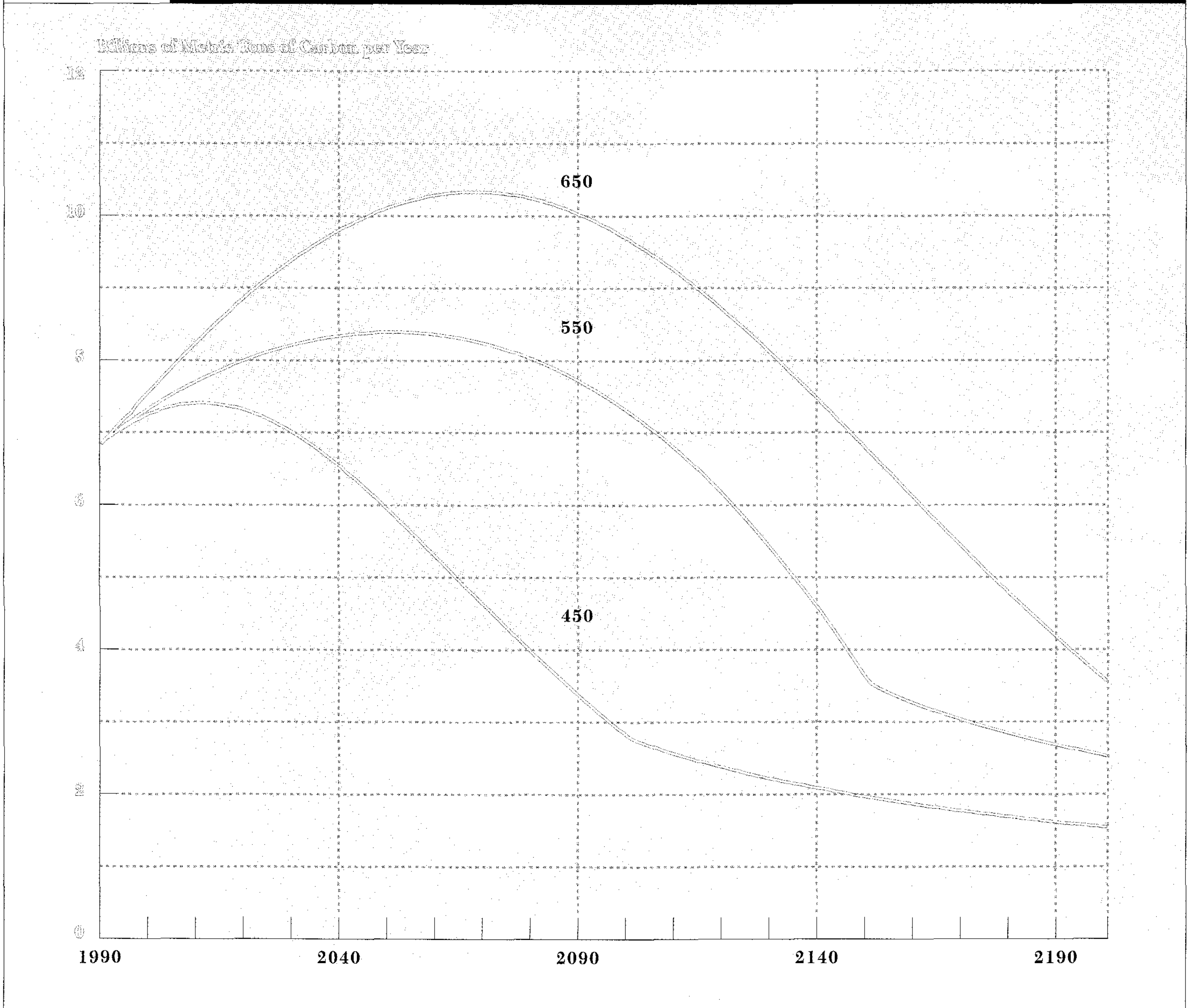
A continued warming of the earth will lead to other impacts. Sea-level rise will threaten cities and countries worldwide. The IPCC's best estimate of sea level rise from 1990 to 2100 is about 49 cm (19 inches).[32] Ocean levels would continue to rise long after the year 2100, however, until the oceans reach thermal equilibrium. Continued sea-level rise would erode barrier islands and virtually eliminate some island chains, such as the island nation of Maldives in the Indian Ocean. Higher seas would inundate the productive coastal wetlands and estuaries upon which marine fisheries and wildlife resources depend; drive millions of people around the world from their homes; cause saltwater intrusion into coastal groundwater supplies; adversely affect nearby infrastructure such as highways, power plants, sewage treatment plants, beaches, and cultural and historical sites; and increase the severity of storm damage to lagoons, estuaries, and coral reefs.

Highly productive agricultural areas such as the deltas of the Nile, Ganges, Yangtze, and Mekong rivers would be seriously affected by sea-level rise, forcing millions of people to move inland. Continued warming would also lead to shifts in rainfall patterns as global precipitation increases, leading to changes in availability of water for irrigation, hydropower, and navigation. Unable to migrate fast enough to keep up with the changing climate, whole ecosystems would be lost.

Scientists expect impacts on agriculture to be mixed. Their models suggest that if carbon dioxide levels double, agricultural production could be maintained at projected baseline rates, though regional effects would vary widely.[33] Still, uncertainties are great and many factors have not been examined for their impacts. The IPCC cautions that the model calculations supporting its conclusions take into account the fertilization effects of CO_2 but "do not include changes in insects, weeds, and diseases; direct effects of climate change on livestock; changes in soil and soil-management practices; and changes in water supply caused by alterations in river flows and irrigation." Failure to integrate many key factors into climate models limits the ability of researchers to consider scenarios in which the climate is still changing and to fully address the costs and potential of adaptation.[34]

Because tropical storms such as hurricanes derive their energy from the oceans, it is possible that as the seas warm, there could be an increase in the number and intensity of such storms. A recent statistical analysis by scientists at the University College London concludes that the record warming of the Atlantic Ocean may have been the primary cause of

FIG. 6 EMISSION PATHS LEADING TO CO_2 CONCENTRATIONS OF 450, 550, & 650 PPM



the exceptional 1995 hurricane season which saw twice the usual number of hurricanes.[35] While the years 1995 and 1996 were the two busiest consecutive hurricane seasons on record, and 1997 is also predicted to be above average (six hurricanes are predicted of which two are expected to be intense),[36] a three-year period is too short to establish a trend. A natural cycle of increased hurricane activity similar to what occurred in the 1940–1960 period may be starting.

If the number of powerful hurricanes—of natural origin or the result of global warming—does increase, damages could be severe, the result of more people living in more expensive homes in vulnerable coastal regions. It is estimated that a class-5 hurricane striking the northeast United States coastal corridor from Delaware to Connecticut could cause over $50 billion in insured losses (perhaps twice that amount in total losses).[37] The prognosis, according to the National Center for Atmospheric Research, is for an increased likelihood of such major storms: "it is only a matter of time before the nation experiences a $50 billion or greater storm, with multi billion-dollar losses becoming increasingly frequent. Climate fluctuations which return the Atlantic basin to a period of more frequent storms will enhance the chances that this time occurs sooner, rather than later."[38] The possibility of devastating property losses has spurred the insurance industry to a growing interest in climate change and in options to reduce their vulnerability to these potentially financially disastrous storms.

COPING WITH CLIMATE CHANGE

Global warming is one of the most important environmental risks affecting long-range planning, particularly in the energy sector. Figure 6 shows several possible "pathways" to various stabilized CO_2 concentrations: 450, 550, and 650 parts per million (ppm), respectively. Major reductions would be needed in CO_2 emissions to reach any of these goals. According to the IPCC, stabilizing atmospheric CO_2 concentrations at twice preindustrial levels (that is, at about 550 ppm) would require eventual reduction of global carbon emissions by at least 60 percent of today's levels. There is no guarantee whatever that a doubling of CO_2 concentration in the atmosphere would be a "safe" concentration.

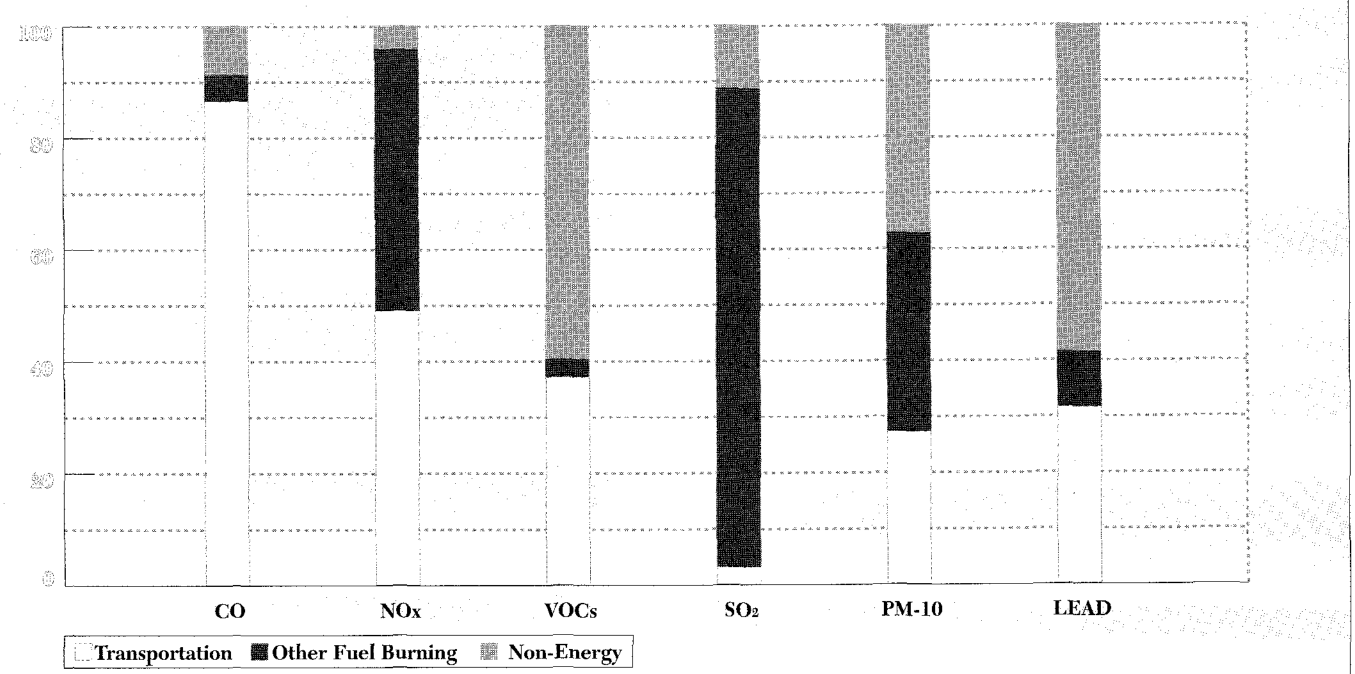
3 AIR POLLUTION

Although U.S. policy-makers have long recognized the public health threat of air pollution, they have often overlooked links between air pollution, energy security, and climate change. As Figure 7 shows, much of the air pollution in the United States arises from fuel burning in transportation, power plants, and buildings. (Air pollution from the burning of fuels is indicated by the black and white portions of the bars.) By far, most of the carbon monoxide, nitrogen oxide, and sulfur oxide emissions come from fuel burning.

According to the Environmental Protection Agency (EPA), about 80 million Americans live in areas where at least one federal air pollution standard was exceeded in 1995.[39] Over the past 25 years, EPA and the Congress have devoted huge resources to combating this pollution and have made remarkable progress in reducing emissions to levels below historical trends. Yet, economic and population growth continually increase the number of energy (and hence pollution) sources and the number of people exposed to pollutants. Moreover, pollution controls deteriorate over time. As a result of both growth and deterioration, EPA expects emissions of carbon monoxide, nitrogen oxides, volatile organic compounds, and small particles to begin rising again.[40] Only sulfur oxide emissions are projected to continue their long-term downward trend, the result of a congressionally mandated absolute limit on utility sulfur emissions.

Examples of the energy-pollution-climate connection abound. Sulfur dioxide (SO_2) arises mostly from coal-burning electric-power production and is a serious air pollutant that contributes to acid rain. While in the atmosphere, SO_2, with the help of moisture and other air pollutants, leads to the formation of small aerosols that have a regional cooling effect, offsetting some of the global warming by scattering sunlight back into space and by helping to form clouds that reflect sunlight. Conversely,

FIG. 7 PERCENTAGE SECTOR CONTRIBUTION TO AIR POLLUTION EMISSIONS (1995)



ground-level ozone is both a harmful pollutant that arises mostly from fossil-fuel burning and a significant greenhouse gas that contributes to global warming. Carbon monoxide, a hazardous air pollutant given off by motor vehicles, is removed from the atmosphere by chemical reactions that have the effect of increasing concentrations of methane, a powerful greenhouse gas. Nitrous oxide (N_2O) is a greenhouse gas and stratospheric-ozone depleter that arises, in part, from the use of catalytic converters that reduce motor vehicle air pollution emissions.[41]

Air pollutants can be roughly grouped according to their sources. Sulfur dioxide (SO_2) pollution arises mainly from coal burning in power plants, while carbon monoxide and ozone (the principal chemical in smog) arise mostly from the emissions of cars, buses, and trucks. Nitrogen oxides (NO_x) and small-particle pollution come from both motor vehicles and fuel-burning power plants; NO_x contribute to both smog and acid deposition. Small particles from fuel burning, industrial processes, transportation, and other sources present serious health risks partly because they can penetrate deeply into the lungs. According to EPA, fugitive dust from roads and construction are a large source of PM2.5 emissions (particles with diameters less than 2.5 millionth of a meter), accounting for nearly 36 percent of primary releases. Home heating with wood is also a large source.[42] Taking into account the small, secondary aerosols formed from utility SO_2 emissions, power plants are the single largest source of PM2.5.

The chemicals involved in acid rain and smog pollution all occur naturally in the air. Sulfur dioxide, nitrogen oxides, hydrocarbons, and ozone all have natural sources such as volcanoes, lightning, and forest fires. The reason that emissions from human activities cause such pollution problems is that they are huge compared with natural emissions. In the United States, for example, sulfur dioxide emissions from human sources, almost all from fuel burning, are about 20 times natural sulfur emissions. Similarly, human-caused emissions of nitrogen oxides (essential for smog formation) are about 10 times natural emissions. With such high emissions, it should come as no surprise that we may be overwhelming natural sulfur and nitrogen cycles, causing health and ecological damage in the process.

Coal is the principal source of sulfur pollution in the United States and is an important source of small-particle air pollution. (Per unit of energy, coal also emits the largest amount of carbon dioxide.) Over the years, electric-power production has become the largest market for coal and the largest single source of SO_2. A similar situation exists in parts of Eastern Europe and in China, where coal is the dominant source of power and is burned with few controls. In some parts of the world, especially in developing countries, SO_2 pollution, primarily from local, ground-level sources, poses significant health risks. In Western Europe and the United States, the sulfur problem primarily involves the impacts of sulfate particles rather than SO_2 itself. These acidic substances adversely affect human health, aquatic systems, forests, monuments, and the regional climate.

Acid deposition has been recognized as an environmental threat since at least the 18th century. The deleterious effects of acid rain on sensitive lakes, forests, soils, and ecosystems have been scientifically documented for more than 30 years. Of long-term concern is the leaching by acids of nutrients from soils. Weakened by nutrient deficiency, trees succumb to combinations of such natural stresses as insects, diseases, wind, drought, and ice storms. Studies suggest that despite the reductions in sulfur emissions required by the Clean Air Act there is still a long-term threat to some forests from the leaching by acid rain of nutrients from the soils and, potentially, from the input of excessive nitrogen.[43]

The effects of acid deposition go beyond damage to soils, trees, aquatic systems, and man-made structures. Recent studies (1994) show that acid rain is causing the decline of several species of songbirds in Europe.[44] In the Netherlands, researchers found that up to 40 percent of certain song birds were laying defective eggs as a result of too little calcium. The birds eat certain snails that were declining because the soils lack calcium, a result of leaching by acid rain. When forests were treated with lime, the snails came back and the egg-thinning problem disappeared.

> **The reason that emissions from human activities cause such pollution problems is that they are huge compared with natural emissions.**

Ozone and photochemical smog result primarily from chemical reactions involving organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. VOCs and NO_x arise from fuel combustion and from industrial and other sources. The ozone (smog) problem is of special concern for several reasons. The problem is widespread and appears likely to be long term. In 1995, 71 million Americans were living in areas where the ozone air quality standard was violated. And according to EPA, the current standard is not adequate to protect public health. Persons exposed to ozone suffer eye irritation, cough and chest discomfort, headaches, upper respiratory illness, increased asthma attacks, and reduced pulmonary function.

Crops and, indeed, all vegetation are damaged to some extent by ozone. Current ozone concentrations cause losses in crop productivity estimated at 5 to 10 percent[45] and annual crop damages are estimated as high as 5 billion dollars. Many studies have demonstrated that photochemical pollutants damage forest ecosystems. Ozone has been shown to be the cause of major declines among pine trees (ponderosa and Jeffrey pines) in California and may be responsible for reduced forest productivity in many U.S. locations.[46] Ozone also attacks various manufactured materials such as rubber.

Carbon monoxide (CO) has no known direct adverse impact on the environment though it can affect chemical reactions in the atmosphere, indirectly augmenting global warming. In 1995, about 85 percent of U.S. CO emissions came from fuel burning, more than 80 percent from motor vehicles. Indeed, over 90 percent of all human-caused CO comes from transportation sources.

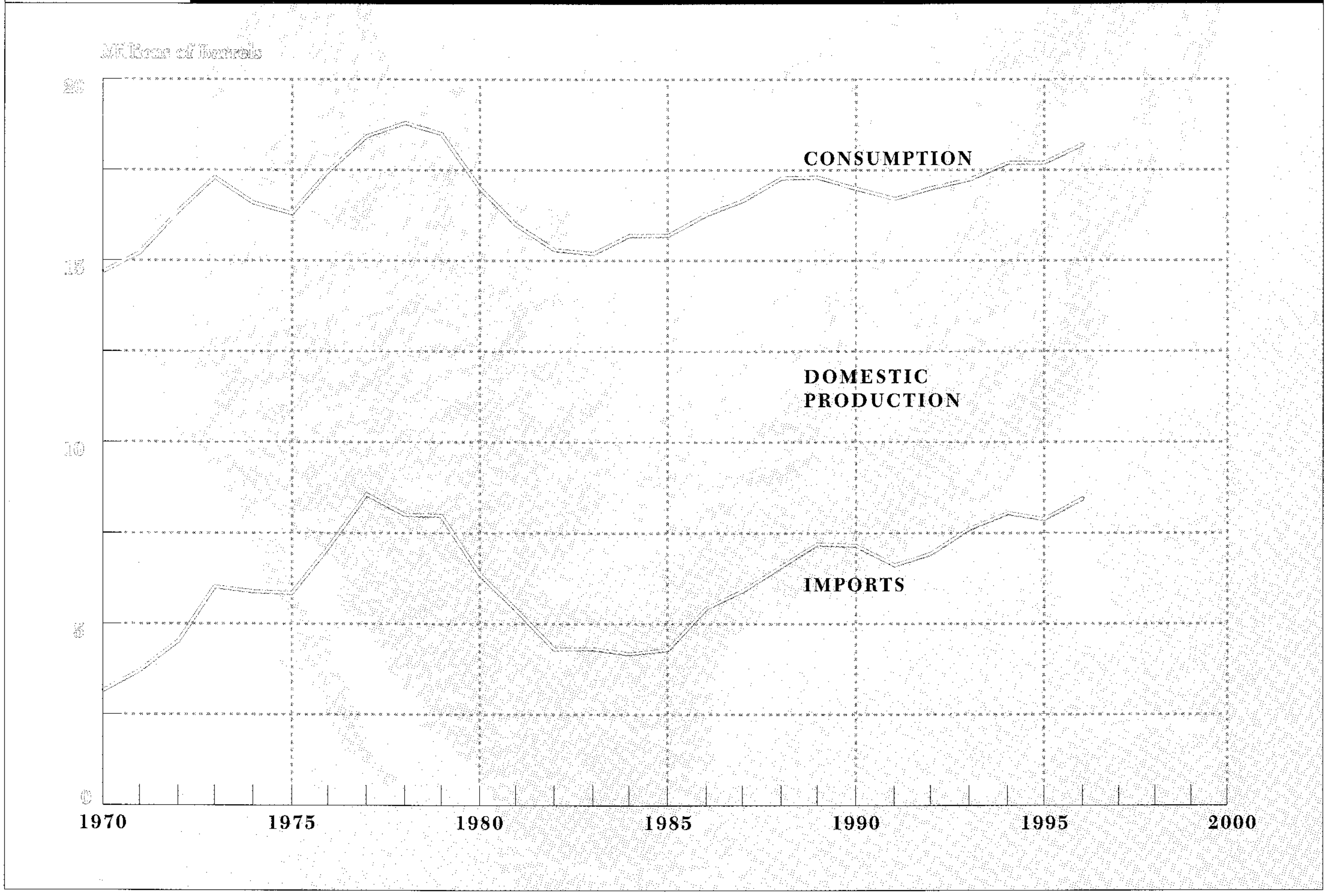
4 OIL SECURITY

Low oil prices over the past few years have made it easy for Americans to ignore their increasing dependence on foreign oil. Meanwhile, the problem has grown more serious. With domestic oil production continuing its long-term decline and oil imports filling the gap, the nation's energy and economic security is increasingly at risk. Oil is a major factor in U.S. foreign policy and its overall trade deficit.

The importance of petroleum products to the economic and energy security of western nations was dramatically highlighted in 1991 by U.S. willingness to go to war with Iraq to ensure access to Persian Gulf oil under favorable conditions. (Even during peacetime the United States spends tens of billions of dollars each year to maintain a military presence in the Persian Gulf.) Paradoxically, while the United States was willing to fight to protect petroleum supplies on the other side of the world, it has no long-term strategy to reduce national dependence on imported oil either by improving energy efficiency or by developing alternative energy sources.

The United States is steadily increasing its reliance on imported oil. Between 1973 and 1996, oil imports to the United States increased by about 40 percent. *(See Figure 8.)* In 1996, about 40 percent of U.S. energy was derived from oil, with net imports of about 46 percent; about 17 percent of imports are from the Persian Gulf. *(See Figure 9.)* By 2015, the Department of Energy expects imports to account for 61 percent of U.S. oil supply.[47] In other words, we are substantially more dependent on imports now than we were in 1973 when we saw how much a disruption in oil supply could hurt, and this dependence is sure to grow. The Strategic Petroleum Reserve—containing about 560 million barrels of oil—could be tapped in an emergency to replace current Persian Gulf imports. But as dependence on foreign supplies grows, our grace period—about a year at current import rates from the Middle East—shrinks.

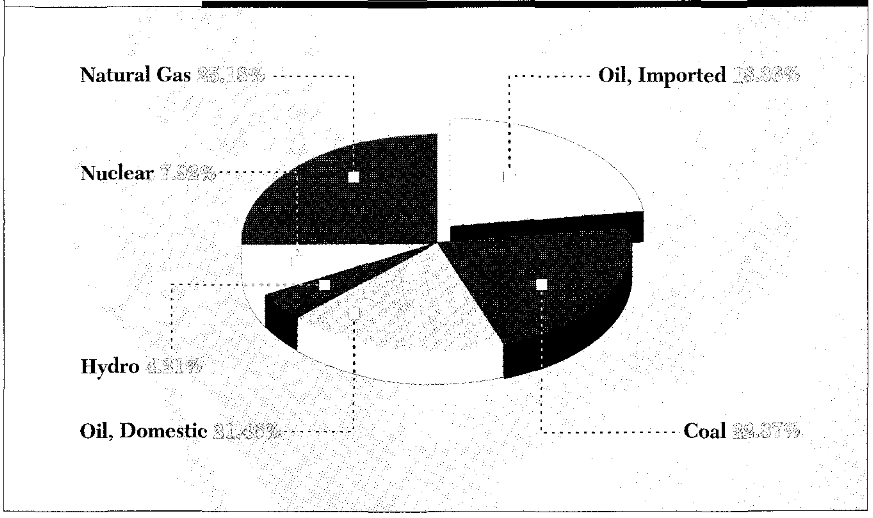
FIG. 8 TRENDS IN U.S. PETROLEUM CONSUMPTION AND IMPORTS



Behind our growing dependence on imported oil is a hard geological reality: the United States is one of the world's oldest oil producing regions, and its oil fields are approaching exhaustion. Eighty percent of all the oil and gas wells ever drilled worldwide are in the United States, and we simply cannot produce nearly as much oil as we now consume. Production in the lower 48 states peaked in 1970 and, except for slight increases in 1984–85, has been declining since. Crude oil production in Alaska peaked in 1988 and has fallen by about 30 percent since. *(See Figure 10.)* It is possible that new oil deposits could be found in Alaska. But even if they were, they would take years to develop and probably provide no more than a decade of minor, temporary relief.

The future for domestic production of crude oil is anything but bright. Crude production in the lower 48 United States has declined by about 45 percent since its peak and is likely to keep sliding downward: the

U.S. SOURCES OF ENERGY (1996)



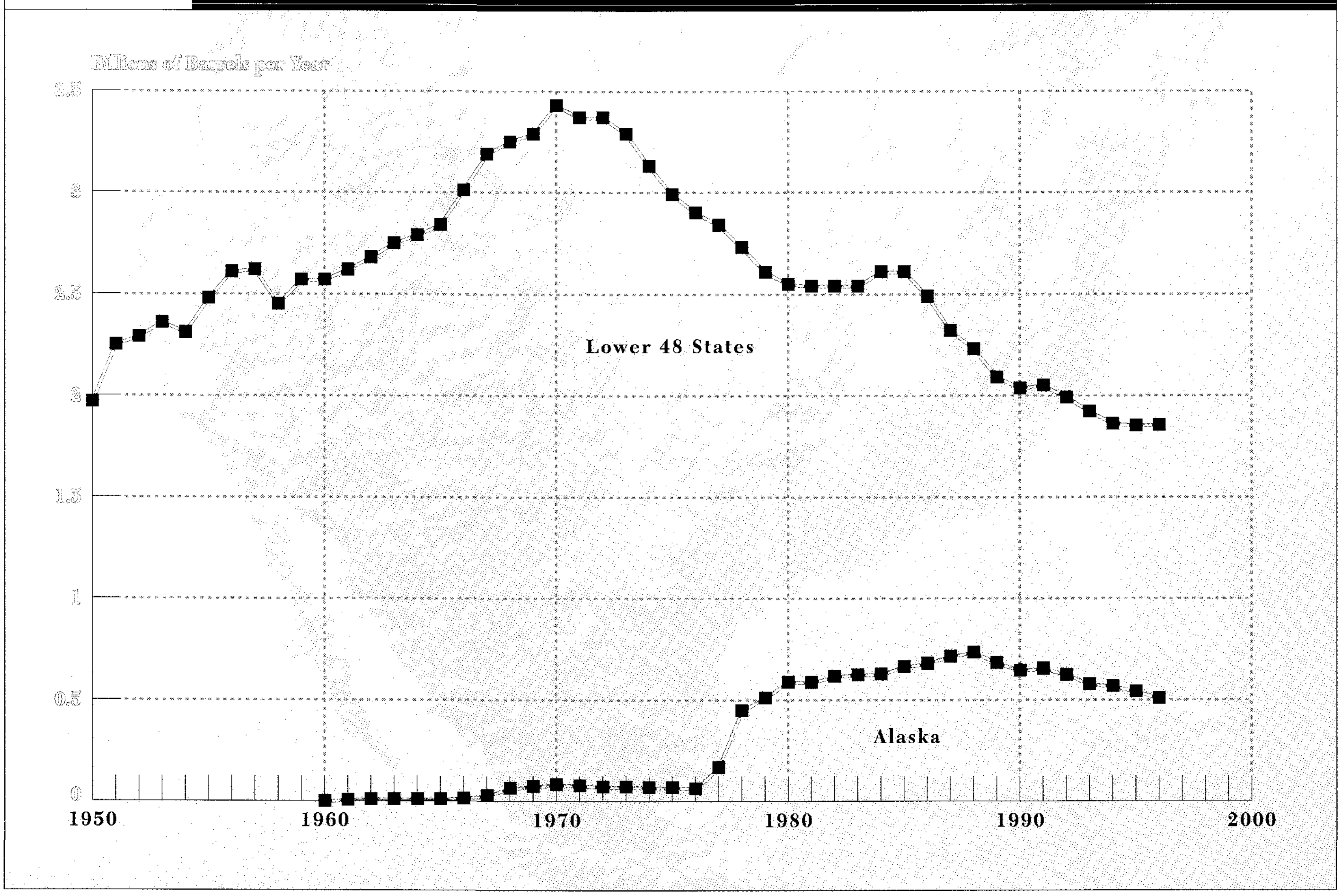
nation has pumped an estimated 85 percent of all the oil likely to be recovered in the lower 48 states.[48] This production slump has not resulted from a lack of effort in drilling and exploration. When world oil prices rose during the 1970s, drilling for oil and gas in the United States intensified, tripling between 1973 and its peak in 1981. Despite this drilling effort, proved oil reserves have continued to fall.

The United States is not the only country strapped for oil and worried about how to get it. *(See Figure 11.)* The Western industrialized nations consume half of the world's oil but possess only 10 percent of global oil reserves. North America (including Canada and Mexico) alone accounts for almost 30 percent of world oil demand. Its share of world proved reserves, though, is only 8.5 percent, with only 2.9 percent in the United States. The Persian Gulf oil producers, representing 5.8 percent of world oil consumption, have about two-thirds of the world's proved oil reserves.

What do these trends in petroleum consumption imply for U.S. national security? Unless the nation gets serious about reducing oil consumption, it will have to import an ever larger fraction of its supply, increasingly from OPEC producers and increasingly from the Persian Gulf. According to the Department of Energy, OPEC's share of world production will rise from about 40 percent of total world production (1995) to almost 60 percent in 2015.[49] And as OPEC regains dominance in world oil production—likely within a decade—so too will the risks of supply disruptions as a result of regional conflicts.

Finally, there are the long-term security and economic risks from the eventual exhaustion of conventional crude oil resources.[50] Oil, coal, and natural gas are fossil fuels formed deep in the earth's crust over millions of years. They are finite and non-renewable and, in due course, will become scarce and costly, requiring the introduction of replacement energy sources. Over the past 50 years, oil companies, geologists, governments, and private corporations have published scores of studies on recoverable global oil resources, which they call Estimated Ultimately Recoverable (EUR) oil. (EUR oil is the total amount of oil that will have been produced when production finally ceases.) Taken together, the great majority of these studies reflect a consensus among oil experts that EUR oil reserves lie within the range of 1,800 to 2,200 billion barrels. As of the

FIG. 10 TRENDS IN U.S. CRUDE OIL PRODUCTION



end of 1996, the world had consumed about 788 billion barrels of these ultimately recoverable reserves.

Given these estimates of recoverable oil, and assuming moderate growth in world oil demand (about 2 percent per year), it is possible to calculate when world production of conventional crude oil might begin to decline, driven by resource constraints.[51] *(See Figure 12.)* At the low end—1,800 billion barrels of EUR oil—peaking of world oil production could occur as early as 2007; at the high end—2,200 billion barrels—peaking could occur around 2013. (An implausibly high 2,600 billion barrels of EUR oil would postpone peaking only another six years, to 2019.)

This analysis does not imply that the world will soon run out of oil or hydrocarbon fuels. Conventional oil production will continue, though at a declining rate, for many decades after its peak. In addition, there are enormous amounts of coal, tar sands, heavy oil, and oil shales worldwide that could be used to produce synthetic liquid or gaseous substitutes for crude oil. But the facilities for making such synthetic fuels are costly to build and environmentally damaging to operate, and their use

FIG. 11 WORLD OIL CONSUMPTION AND PROVED RESERVES (1996)

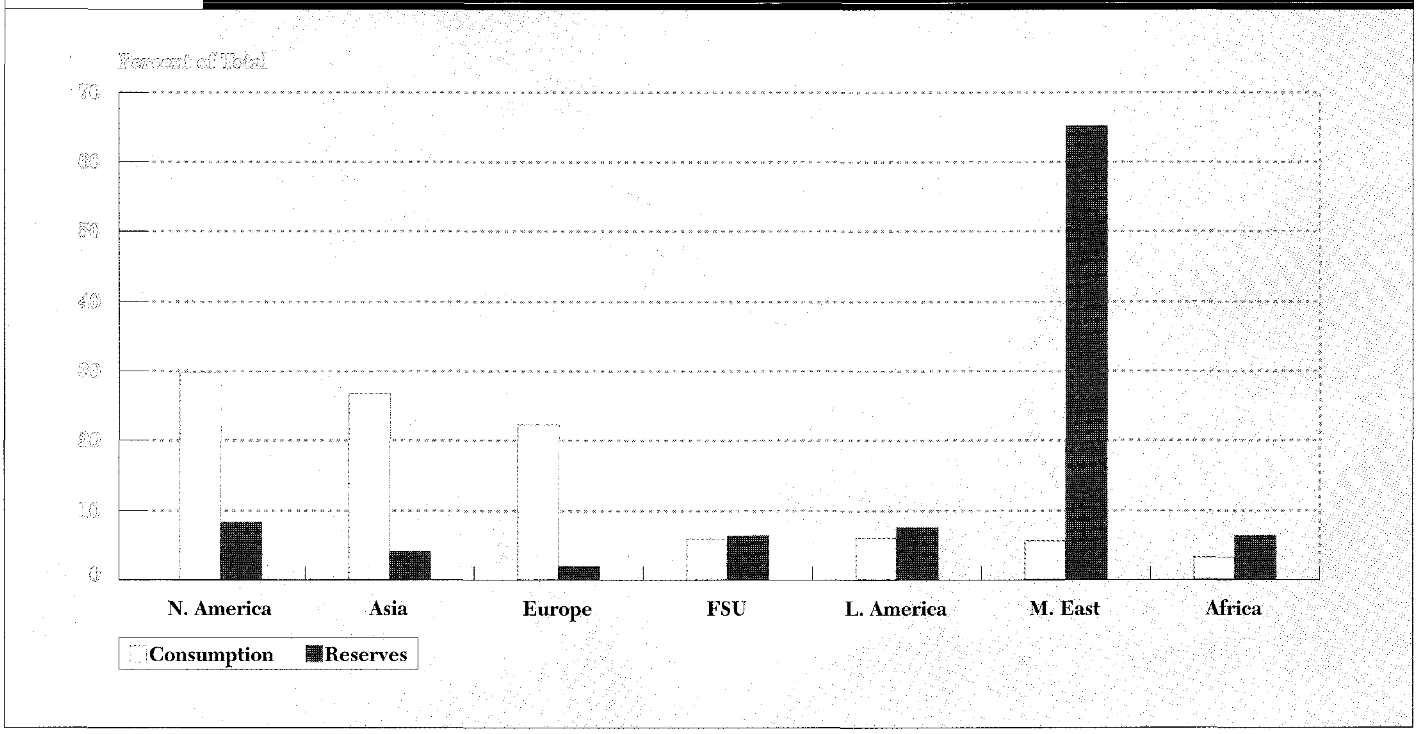
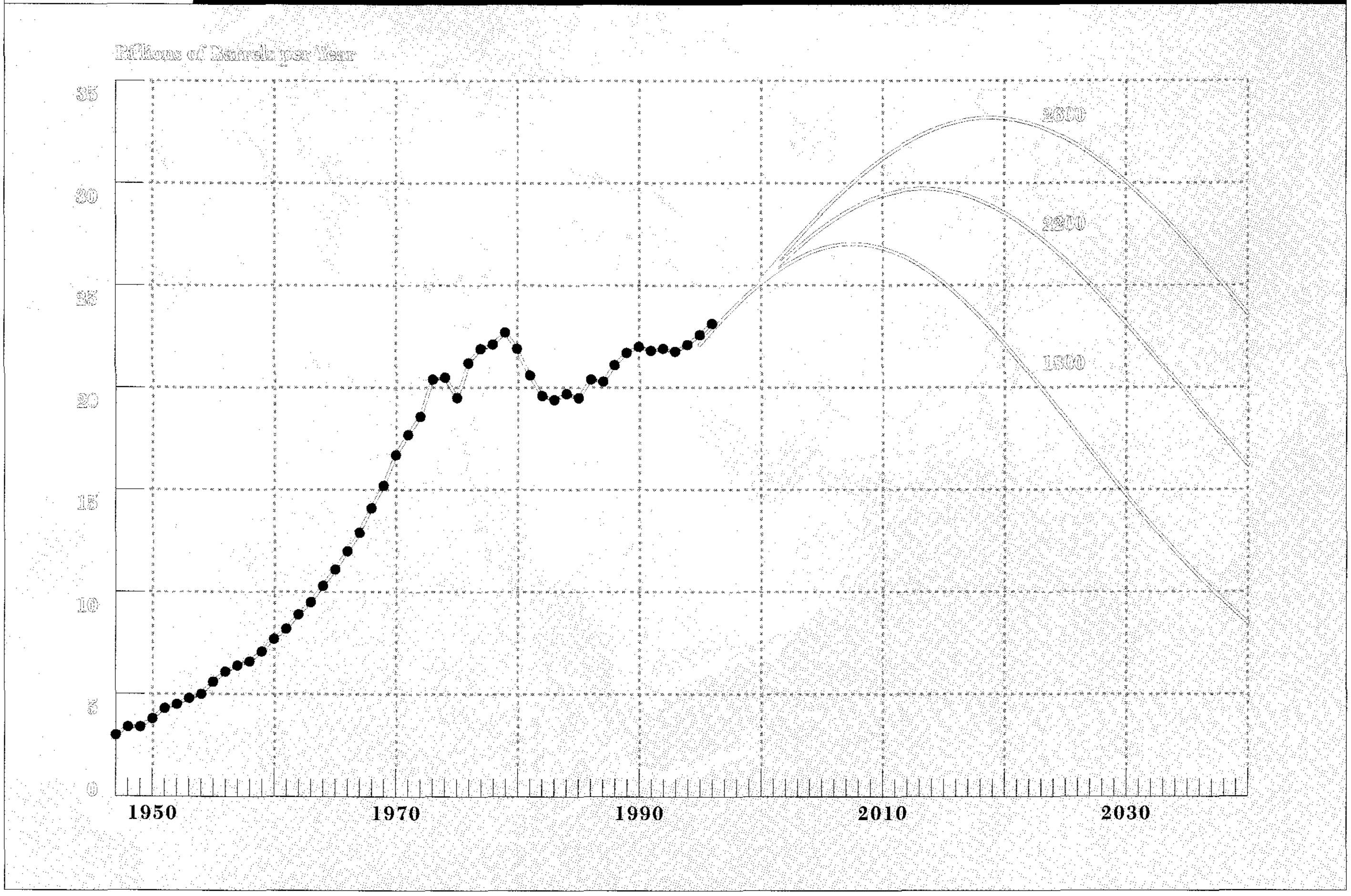


FIG. 12 GLOBAL OIL PRODUCTION FOR RESOURCES OF 1800, 2200, 2600 BILLION BARRELS



would substantially increase carbon dioxide emissions compared to the use of products made from conventional crude oil.

As global oil production approaches its peak, there will be upward pressures on world oil prices from their present low levels, though by how much and how fast they might rise remain uncertain. The economic impacts will depend largely on the price and availability of energy alternatives and the rate at which production declines. Transportation, almost totally dependent on oil, could be especially hard hit unless vehicles fueled by sources other than oil are developed and rapidly deployed. As the peak and decline of world oil production comes within sight, we urgently need policies to encourage more efficient oil use and reliance on alternative energy sources, especially in transportation. Unfortunately, because oil prices are low, few decision-makers appreciate how little time remains. Efforts on both of these accounts are weak and overdue.

5 LINKED PROBLEMS, LINKED SOLUTIONS

The problems of greenhouse warming, air pollution, and oil security are intimately linked through the gases, pollutants, and technologies associated with fossil fuel combustion. If these linkages are not respected, haphazardly adopted strategies developed to deal with the problems individually might alleviate one only to exacerbate another.

Measures to cope with these problems will affect all energy-consuming sectors of the economy (buildings, industry, transportation, and utilities). Buildings and factories will have to become more energy efficient, reducing their on-site fuel use for heating, cooling, refrigeration, and lighting. Especially significant will be the changes in power generation and transportation. These two sectors account for almost two thirds of U.S. energy consumption and are the two largest sources of CO_2 emissions.[52]

> **To be absolutely clear—we must now focus on what can and what should be done, not because we can be certain climate change is happening, but because the possibility can't be ignored.**
>
> *John Browne, CEO, BP*
> *at Stanford University*
> *May 19, 1997*

Figure 2 shows that direct CO_2 emissions from buildings and factories have remained fairly steady while those from power plants and transportation have been growing. Electric power plants account for about 36 percent of CO_2 emissions,[53] and for the most part the utilities believe they have little choice but to burn fossil fuels. The growth in utility CO_2 emissions reflects the long-term trend toward electrification of the economy. Consumers are increasingly buying their energy in the form of electricity rather than as coal, oil, or natural gas.

Transportation currently accounts for 30 percent of U.S. carbon dioxide emissions, 80 percent of carbon monoxide releases, 49 percent of nitrogen oxides, and 37 percent of organic compound emissions.[54]

BOX 3

CONFLICTING NATIONAL POLICIES— THE PERILS OF IGNORING LINKAGES

- Motor vehicles are major sources of air pollution and are the fastest growing source of carbon dioxide emissions. Vehicles also account for about half of U.S. oil consumption, equivalent in volume to all imports. Sensible domestic policies to address climate change, air pollution, and energy security would prescribe a long-term strategy to introduce emissionless vehicles ultimately powered by non-fossil energy sources. This is far from the case. Both the Clean Air Act and the Energy Policy Act broadly encourage the use of virtually any alternative fuel that has some potential clean air benefit including methanol, ethanol, compressed natural gas, and even synfuels made from coal.[a] These fuels have only marginal clean air benefits and little or no climate benefit. Their widespread use would frustrate attempts to reduce greenhouse gas emissions. Policies on federal fleet purchases are only compounding the problem. In 1995, the federal government purchased almost 19,000 alternative fuel vehicles of which less than 0.3 percent were emissionless; the rest burn fossil fuels or ethanol made from corn and offer little climate benefit. In short, federal policies on alternative fuels fail to recognize the links between motor vehicle fuels and the problems they give rise to.
- The United States is a major factor in the climate problem: with less than 5 percent of the world's population, the United States accounts for about 22 percent of global energy-related CO_2 emissions. Despite the need to curtail CO_2 releases, U.S. emissions continue to rise (almost 9 percent between 1990 and 1996), paced by transportation and electric-power production. Given the critical need to begin the transition to renewable energy sources, federal research, development, and demonstration resources should be focussed on beginning the move to renewables. Instead, the budget heavily emphasizes the burning of fossil fuels. In Fiscal Year 1997, the Congress appropriated $267 million dollars for solar energy technologies but $365 million dollars for fossil fuel research and development. Federal priorities seem out of sync with the urgent challenge to begin the transition from fossil to sustainable energy sources.
- In 1991, the United States went to war to ensure continued access, on favorable terms, to Persian Gulf oil. Yet, neither the Congress nor the Administration will support the kinds of domestic measures that would help cut U.S. oil dependence and enhance national security.
  - In constant dollars, fuel prices are near an all-time low. Yet, there is no support for a revenue-neutral increase in the fuel tax (offset by reductions in taxes on income and investment) that would reduce the growth rate in oil consumption and increase the economic attractiveness of non-petroleum technologies such as electric-drive vehicles.
  - With federal approval, speed limits on interstate highways have been greatly increased despite the fact that higher speeds lead to significant drops in vehicle fuel efficiency. Tests by DOE's Oak Ridge National Laboratory show that cars consume 33 percent more fuel to drive a mile at 75 mph than at 55 mpg.[b]

Box continues on page <None>

[a] "Comparative Alternative /Clean Fuel Provisions of the Clean Air Act and the Energy Policy Act," Alternative Fuel Information, US Department of Energy.

[b] Stacy C. Davis and David N. McFarlin, "Transportation Energy Data Book: Edition 16," USDOE, Oak Ridge National Laboratory, ORNL-6898, pp. 3–47.

Conflicting National Policies—The Perils of Ignoring Linkages (Continued)

Hence, federally sanctioned higher speed limits encourage greater fuel consumption and higher CO_2 emissions.

- The average fuel efficiency of new cars and light trucks (including minivans and sport utility vehicles) has been dropping since 1987, largely the result of all-time lows in fuel prices. Despite the clear security and environmental threats engendered by this trend, the federal government has done little beyond sponsoring a long-term "Big Three" research program (PNGV—the Partnership for a New Generation of Vehicles) that will have little discernible effect on U.S. oil consumption for many years.
- Federal legislation to encourage the use of alternative fuels—such as ethanol—actually encourages the sale of less fuel-efficient new vehicles.[c] This is so because the federal fuel-efficiency standard (Corporate Average Fuel Efficiency, CAFE) for multi-fuel vehicles permits automakers to take an effective efficiency credit much higher than the vehicle's measured value running on gasoline. Ford and Chrysler, unable to meet their gasoline CAFE standard, will build new vehicles capable of running on 85 percent ethanol even though these vehicles are almost certain never to operate on the fuel. Up to 40 percent of Chrysler's future minivan fleet will come under this provision. As a result, Chrysler's minivans will be rated at about 133 mpg rather than the actual 20 mpg, regardless of what fuel is used in the vehicles.

In short, by sins of both omission and commission, federal policies are exacerbating the linked energy problems of climate, pollution, and oil security.

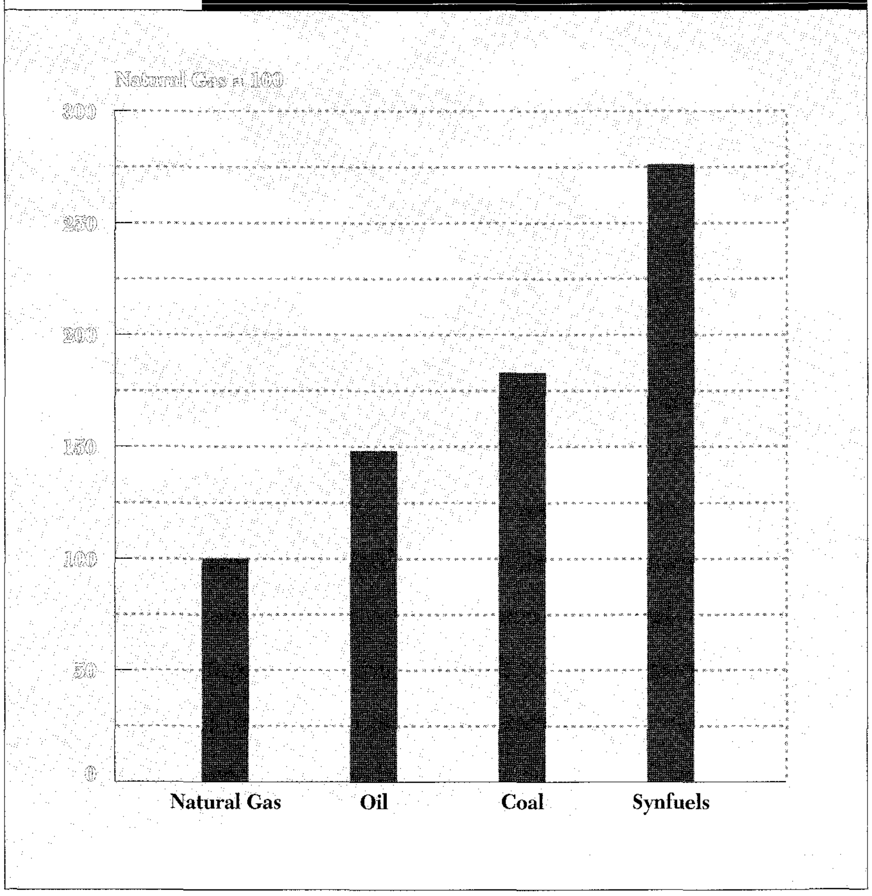
[c] Dale Jewett, "Makers' Ethanol Plan Provides Federal Fuel-Economy Bonus," *Automotive News,* June 23, 1997; Southeastern Regional Biomass Energy Program, "Update," July 1997.

Emissions of air pollutants from transportation are projected to grow in the future. Transportation also accounts for nearly two thirds of oil consumption and so is a major factor in the nation's increasing reliance on imported oil. The continued growth in transportation emissions reflects, in part, the decline in the real cost of driving. In real terms, a gallon of gasoline costs a third less in 1995 than it did in 1950—and less than a gallon of bottled spring water.

It is clear that if we are to come to grips with our three-pronged energy problem, fundamental long-term changes will have to occur in the way electric power is generated and motor vehicles are powered. In the near term, the various pollution and climate risks that we have outlined can be reduced through improved energy efficiency and fuel substitution. Energy efficiency is the most effective means available for dealing with these intertwined problems and it must be the cornerstone of long-term change. Moreover, improved efficiency will also increase U.S. competitiveness in world markets.

In terms of their carbon and pollution emissions, the fossil fuels differ significantly. Natural gas combustion emits the least amount of CO_2 and air pollution per unit of energy. Oil emits between 38 and 43 percent more CO_2 than natural gas, and coal, between 72 and 95 percent more.[55] *(See Figure 13.)* Synthetic oil made from coal (produced, for example, to reduce oil imports) emits much more CO_2 than conventional oil. From both climate and air pollution perspectives, natural gas is the most attractive fossil fuel and synthetic fuels are the least. Over the long run, the use of more sustainable, non-fossil energy technologies will have to be greatly expanded if fossil fuel CO_2 emissions are to be controlled. How this might happen and what their effects would be on our economy are outlined next.

FIG. 13 **RELATIVE CARBON DIOXIDE EMISSIONS**



ELECTRIC POWER PRODUCTION

Increased efficiency in power generation and consumption is the first priority in reducing CO_2 emissions by utilities. Improvements in efficiency would yield double dividends by both reducing carbon emissions and cutting releases of sulfur and nitrogen compounds. Benefits of efficiency include reduced greenhouse warming (by cutting carbon dioxide), less acid deposition (by reducing sulfur and nitrogen emissions), and lower concentrations of ground-level ozone (by limiting the nitrogen oxides that ozone needs to form).

Power plant emissions of sulfur and nitrogen pollution could also be reduced by using cleaner, more efficient generating technologies such as the new highly efficient gas turbines; by installing "clean-coal" technologies (some of which, however, could increase CO_2 emissions); or by switching to comparatively cleaner fuels, such as natural gas. More efficient lighting, refrigerators, heat pumps, water heaters, and industrial machinery all represent economically attractive opportunities to reduce carbon and pollution emissions at attractive costs.

To control the greenhouse problem over the longer term, measures in addition to efficiency improvements will be needed in the production of electric power. Neither "clean-coal" technologies nor any other practical technology now on hand can remove and dispose of the enormous quantities of carbon dioxide that fossil fuel burning sources would produce in the coming years.[a] Today, the only two long-term candidates for electric-power production are the renewable sources (such as solar cells, wind turbines, hydropower, solar thermal, and biomass), and nuclear power. With either source of energy, air pollution—high levels of ozone, acid deposition, carbon monoxide, and particulates—would largely disappear. Renewable electricity technologies—especially solar cells and wind turbines—are strong candidates for future power production and are already supplying power for some utilities. Despite this trend, the use of renewable technologies by utilities could be in jeopardy with the restructuring of the power industry that is occurring. Under most proposals, electric power producers will have little incentives to use anything but the cheapest possible source of electricity, which for the most

[a] To appreciate the enormity of this storage problem, consider that the United States emits about 100 trillion cubic feet of CO_2 each year from burning fuels, mostly from dispersed sources. This is about 5 times the volume of gas handled by the entire U.S. natural gas industry.

part will not be renewables—at least not in the near future. Several factors could affect this situation. Some consumers may prefer to purchase "green" power even if it is somewhat more expensive. Secondly, if a sizable carbon tax were imposed, renewable energy sources would become more financially attractive. Lastly, under some proposals, power producers will be required to generate minimal amounts of power from renewable sources.

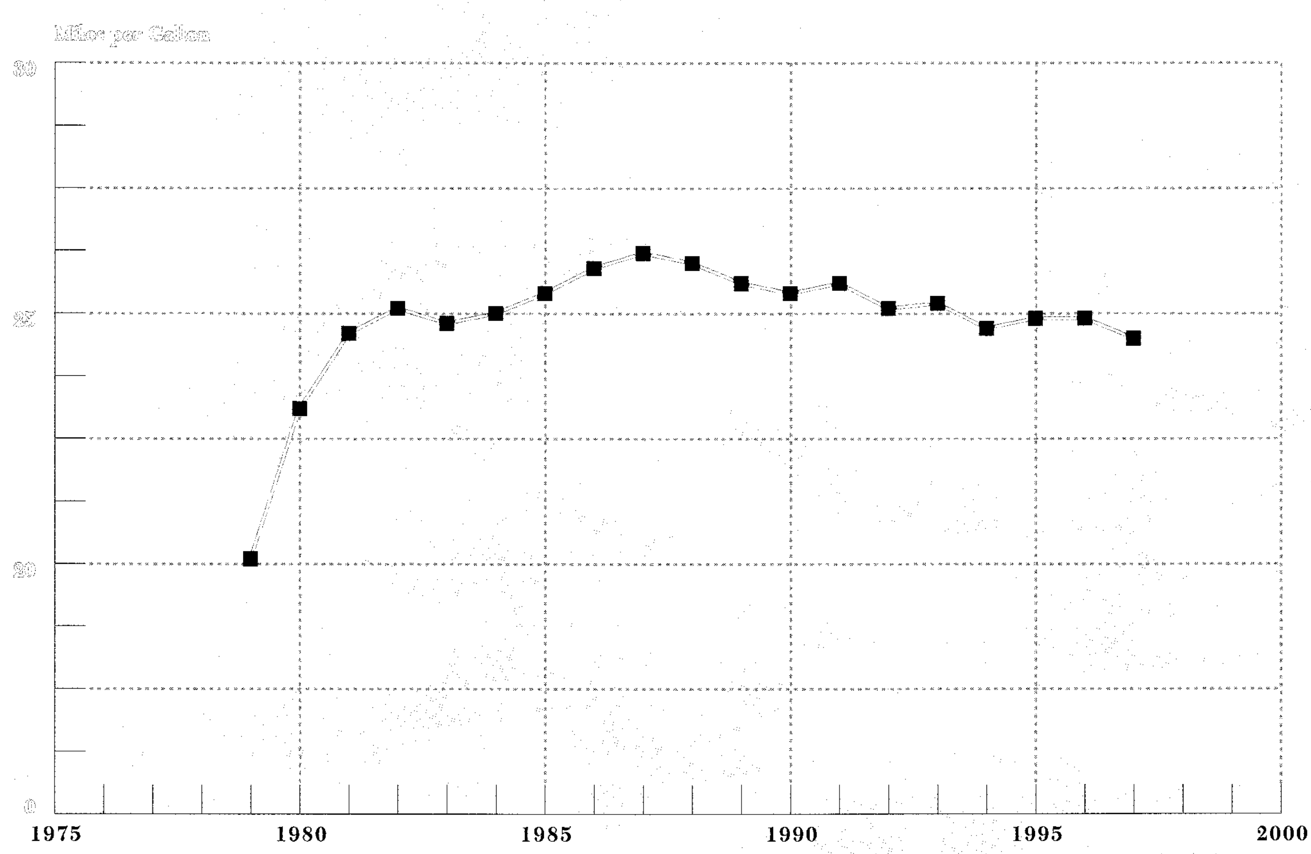
Solar sources are particularly appropriate for decentralized, off-grid applications and the costs of several renewable technologies are dropping. Still, accelerated research on solar cells, wind technologies, and energy storage (for example, using hydrogen, flywheels, and batteries to store energy for later use) is needed. Subsidized purchases of renewable energy technologies to expand markets and reduce costs would also represent money well spent.

Nuclear power's comeback in the United States seems unlikely, at least for the near term. Today's nuclear plants—light-water reactors—have proven complex and expensive to build and operate. With restructuring in the wings, risk-conscious U.S. utilities seem unlikely to order any more. The prospect of second-generation nuclear technologies (smaller, passively safe, fuel-efficient, standardized fission reactors without plutonium recycle) offers a potentially more attractive alternative, but bringing these reactors to market could take decades. Public acceptance would also almost certainly require significant progress on the problems of radioactive waste disposal and plutonium proliferation.

TRANSPORTATION

As we have seen, transportation is a major source of greenhouse gases and air pollution and the largest consumer of oil. Several measures would help solve all three transportation-related problems at the same time. As with power production, improving transportation efficiency is first on the list. If U.S. cars, trucks, and buses were more fuel efficient, oil consumption and carbon dioxide emissions would drop, less oil would have to be imported, and the rate of greenhouse warming would slow down. The good news is that the technology

FIG. 14 TRENDS IN FUEL EFFICIENCY OF NEW LIGHT DUTY U.S. VEHICLES

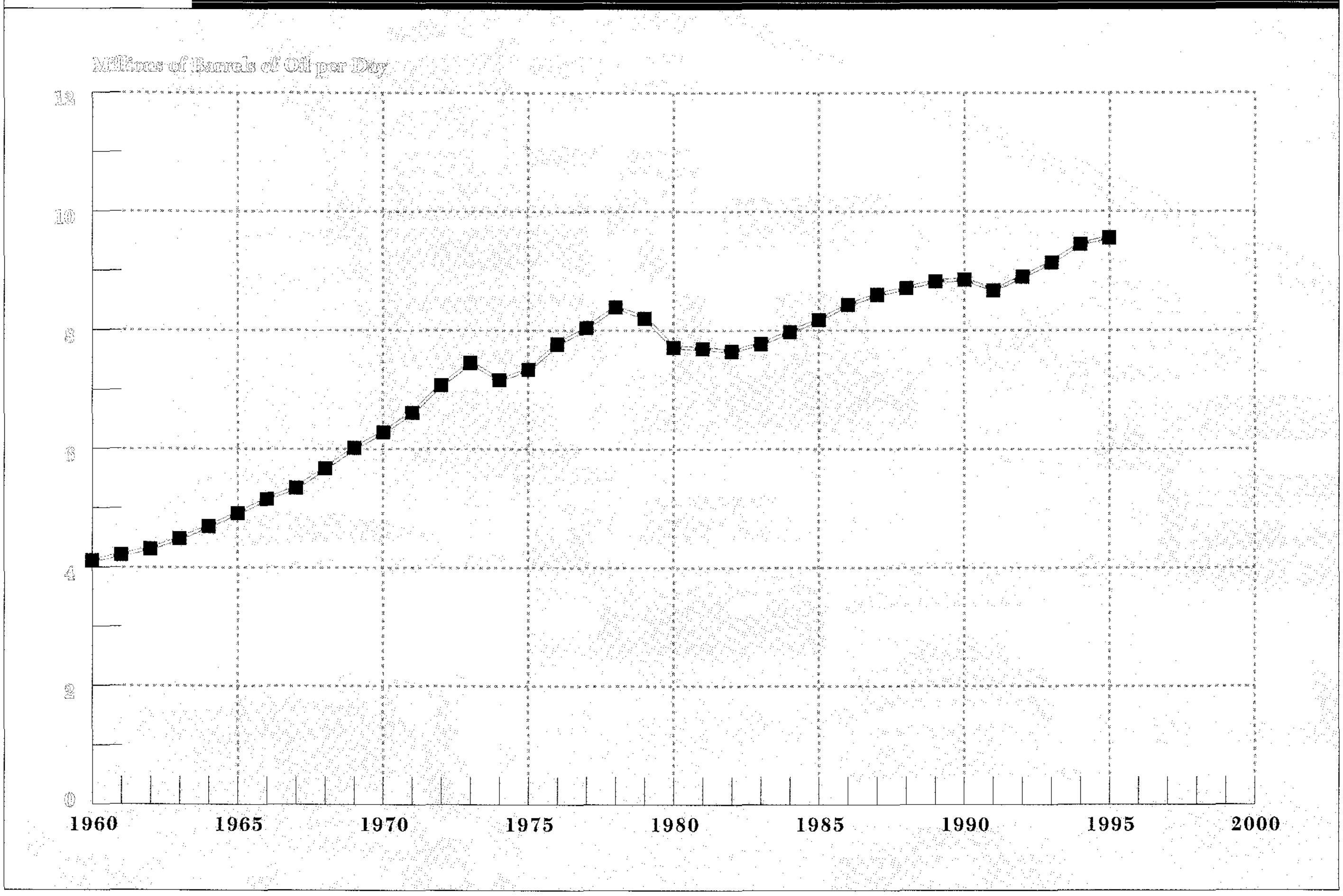


needed to greatly increase transportation fuel efficiency is largely in hand. If Americans gradually replace their gas guzzlers with more efficient vehicles, the risks associated with spiraling oil imports as well as the risks of climate change will decrease. The bad news is that the trend in new-vehicle fuel efficiency is downward, not upward, as consumers are buying more light-duty trucks (sport-utility vehicles, minivans, and pick-up trucks) to meet their personal transportation needs. About 40 percent of new personal vehicles fall into the light-duty truck category, and they are much less fuel-efficient than cars. (According to tests by Consumers Union, typical sport-utility vehicles have a fuel efficiency of about 10 mpg in city driving.) The average fuel efficiency of new cars and light trucks taken together peaked at 26.2 mpg in 1987 and had fallen to 24.8 mpg by 1995. *(See Figure 14.)* This drop in new-vehicle fuel efficiency combined with sustained growth in the number of drivers and vehicles add up to a continued increase in gasoline consumption. *(See Figure 15.)*

Improved new-vehicle fuel efficiency encouraged through market mechanisms would be an important first step toward reducing motor-vehicle CO_2 emissions. For all its benefits, though, it seems unlikely that new-car fuel efficiency can rise fast enough to overcome the momentum of increased vehicle use. Motor vehicles depend totally on a depletable fossil fuel—oil. Until economically and technologically attractive alternative fuels become widely available, we will not be able to solve the problems engendered by motor vehicle use; consumers will have little alternative other than to continue buying oil-powered cars and trucks.

The world needs alternatives to oil-powered vehicles.[56] And the burden for developing the technological alternatives rests squarely

FIG. 15 TRENDS IN U.S. MOTOR VEHICLE FUEL CONSUMPTION



on the industrialized countries that make them: 80 percent of these vehicles are made in the United States, Japan, and Europe. No one else can do it. Various carbon-based fuels, burned in internal combustion engines (ICE), are being promoted as substitutes for gasoline to reduce air pollution. These fuels include blends of gasoline and methanol (wood alcohol) or ethanol (grain alcohol, made from corn) and compressed natural gas (CNG). Methanol (as presently produced) and CNG are based on fossil fuels, and their use is not sustainable over the long haul. *Moreover, they offer little if any improvement over gasoline in* reducing greenhouse gas emissions. As for air pollution, CNG offers benefits while methanol-gasoline blends could actually increase ozone formation. The widespread deployment of methanol or CNG in ICE vehicles should not be encouraged.

Ethanol produced from corn, for use in gasohol, is also not a long-term solution. In 1995, about 9 percent of the motor-vehicle fuel pumped at service stations in the United States was gasohol, a mixture of 10 percent ethanol and 90 percent gasoline. Ethanol production is heavily subsidized by the federal government ($0.54 per gallon) and various agricultural states. Gasohol probably offers no ozone benefit.[57] And it takes large amounts of fossil fuels to make. Under very favorable circumstances, ethanol derived from corn has an energy ratio of only 1.24.[58] That is, ethanol production yields only 24 percent more energy than is used in making it.

Viewed solely as a means of cutting air pollution, these fuels have varying degrees of merit. All three would reduce carbon monoxide emissions relative to conventional gasoline. CNG would also reduce ozone concentrations. But when the impact of these fuels on global warming is taken into account, their attractiveness fades.

ZERO EMISSION VEHICLES: ELECTRIC AND HYDROGEN CARS

The vehicles most capable of dealing with pollution, climate change, and oil security are electric-drive vehicles (EVs) powered by batteries, flywheels, or hydrogen fuel cells. Powered by electric motors they have no combustion engine on board. As a result, they are Zero Emission Vehicles (ZEVs), at least as far as the vehicle itself is concerned. Of course, somewhere there is an energy plant making electricity or hydrogen, and the emissions of these plants must be evaluated to determine the total impact of the EVs.

How much battery-powered electric vehicles can cut CO_2 emissions depends mostly on two factors: the electrical efficiency of the vehicles, and the emissions from the power plants that produce the electricity used to charge them. If EVs are charged by electricity from natural gas power plants (steam), carbon dioxide emissions would fall by about 50 percent compared with comparable gasoline vehicles.[59] In contrast, charging EVs with electricity generated from coal would cut greenhouse gas emissions by only about 20 percent. Charging from oil-fired plants would reduce emissions by about 30 percent. In the longer term, CO_2 and pollution emissions could be entirely eliminated by using renewable energy technologies to charge the batteries. Regardless of which fuel is used to generate the electricity, EVs could be powered strictly from domestic sources, improving both national security and the nation's balance of trade. Switching to battery-powered EVs would significantly reduce emissions in urban areas—EVs emit no street-level pollutants. If the batteries were charged at night avoiding peak power demands during the day, no new power plants would have to be built. Ozone, which cannot form without sunlight, would be reduced. No matter how they are recharged, the use of EVs would lead to reduced oil consumption. The greatest reduction would come from recharging them without burning oil.

HYDROGEN-POWERED FUEL-CELL VEHICLES

Hydrogen-powered EVs generate electricity using a fuel cell, a battery-like device that converts hydrogen and oxygen directly into electricity, water, and waste heat. The electricity is used to power the vehicle using electric motors. Prototype hydrogen-powered cars and buses have been tested both in the United States and overseas. Production of hydrogen using electrolysis of water is the most likely long-term source of hydrogen with the primary energy supplied by non-fossil energy sources such as renewable technologies. In this case, virtually no carbon dioxide emissions would result.

Hydrogen vehicles have at least two potential advantages over battery EVs—longer range and faster refueling. Yet, their widespread commercial use is farther down the road because of the lack of a supporting infrastructure (such as hydrogen pipelines), high fuel-cell prices, and bulky and heavy hydrogen storage systems.[b] Still, like electric vehicles, they would form a natural link in developing a sustainable energy system. Their use would reduce oil imports, alleviate trade deficits, and cut air pollution and greenhouse gas emissions.

[b] Hydrogen is commonly stored on a vehicle as a high-pressure compressed gas. It could also be carried chemically incorporated within methanol (CH_3OH), an easily storable liquid. On board the vehicle, the hydrogen would be chemically extracted from the methanol and used to power the fuel cell. Net carbon dioxide emissions would be small if the methanol were produced from biomass. The long-term sustainability of large-scale biomass production remains to be established.

Battery- or hydrogen-powered electric vehicles, re-fueled eventually by emissionless power sources such as wind turbines, photovoltaic cells, or other sustainable energy sources, will serve as a major element of a sustainable transportation system.

NEXT STEPS

It is clear from this report that new energy technologies are emerging that will reduce the unwanted side effects of burning fossil fuels while enhancing environmental and national security. Their development and use offer major opportunities for the Americana business community. With the emergence of new energy technologies such as solar cells, wind turbines, solar thermal collectors, electric-drive vehicles, batteries, and flywheels, a long-term transition is beginning toward a sustainable U.S. energy sector. The trend toward electrification of the economy will continue as fossil-fuel burning gradually gives way to direct electricity production using these new technologies. As costs fall, a global transition to their use will take hold. The move to sustainable technologies will pose major challenges to humanity as we struggle with the economic and institutional barriers to change. Our success in making this first transition will provide a clue to how successful we will be in introducing sustainability into other sectors of the economy.

What can be done to encourage these trends? An approach is sketched out here that relies primarily on market mechanisms to drive the transition. In the short term, national policies should emphasize improving energy efficiency throughout the economy. This can best be encouraged by reforming energy prices to better reflect the climate, pollution, and security costs levied on us all by fossil fuel consumption. Only with such reforms can the environmental and climate benefits of efficiency and renewable energy be fully realized in the market place.

Nor need there be undue concern that the kinds of energy pricing reforms advocated here will have a negative impact on national economic growth. According to a recent World Resources Institute report, under favorable conditions (described below), U.S. fossil-energy consumption can be cut substantially over the coming decades without lowering projected growth in GDP.[60] Some of the favorable conditions necessary for this outcome are:

- There must be available non-fossil alternative energy sources at competitive prices in the near future;
- Firms and consumers must be flexible and adaptive in their responses to market signals;
- There should be options to trade CO_2 emission rights internationally (so-called Joint Implementation);
- Revenues collected from policies to reduce emissions (either through a tax or through the auction of emission permits) must be used ("recycled") to reduce taxes on income and investment; and
- Economic savings from reduced air pollution and climate damages should be taken into account.

The models that do embody these assumptions indicate that carbon emissions can be cut while the economy continues to grow. Ensuring that some of these conditions are met is, in turn, primarily a matter of public policy.

The market approach advocated here can be coupled with programs of consumer education and energy labeling. Over the longer term, federal and state buying powers can be harnessed to expand the markets for emissionless vehicles and renewable energy technologies. Federal funding is also warranted for basic technological research and development, and for the demonstration of advanced technologies that are nearing commercial competitiveness.

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