CHAPTER TWELVE

Climate Change

The effort to understand and respond to the risks of global climate change entered a critical period in the mid-1990s.

At the end of 1995, the Intergovernmental Panel on Climate Change (IPCC) released its Second Assessment Report. Prepared by 2,500 of the world's leading experts on climate change, this report provides an exhaustive review of all aspects of climate change and its health, environmental, and economic impacts. The report concludes that "the balance of evidence suggests that human activities are having a discernible influence on global climate."

Efforts to address the risks of climate change have moved forward under President Clinton's Climate Change Action Plan, though reduced Congressional funding has limited the plan's effectiveness. By the end of 1995, over 5,500 businesses, schools, churches, and state and local governments were participating in voluntary programs under the plan aimed at reducing net emissions of greenhouse gases. These activities will reduce greenhouse gas emissions by millions of metric tons of carbon equivalent, saving United States' industries and consumers billions of dollars in reduced energy costs.

International efforts to limit greenhouse gases have focused on discussions underway to strengthen the Framework Convention on Climate Change (FCCC). Originally signed at the Rio Summit in 1992, the convention includes a "non-binding aim" of stabilization of greenhouse gas emissions at 1990 levels in the year 2000. In July 1996, at the Second Conference of the Parties to the Climate Convention, the United States announced its support for a framework based on "realistic, verifiable, and binding" medium-term targets that would include the use of trading to enhance flexibility and reduce costs. The current round of negotiations under the Climate Convention is scheduled to conclude in December 1997.

BACKGROUND

The IPCC's recently completed Second Assessment is the scientific community's most exhaustive and thorough review to date of issues related to climate change. Key findings from the IPCC report include the following:

Physical Climate System

- The atmospheric concentrations of greenhouse gases and aerosols are increasing because of human activities.

- Greenhouse gases tend to warm the atmosphere, and sulfate aerosols cause regional cooling. Most greenhouse gases will remain in the atmosphere for many decades to a century or more; sulfate aerosols are removed after several years.
- The Earth's surface temperature has increased by about one degree Fahrenheit over the last century.
- Sea level has increased 4-10 inches during the last century, and mountain glaciers are retreating worldwide.
- Models that account for the observed increases in the atmospheric concentrations of greenhouse gases and sulfate aerosols are simulating the recent history of observed changes in surface temperature with increasing realism.
- The balance of evidence suggests a discernible human influence on the Earth's climate, remaining uncertainties notwithstanding.
- Without global climate-specific policies to mitigate greenhouse gas emissions, the Earth's temperature is projected to increase by roughly 2 to 6 degrees Fahrenheit by 2100, a rate of warming faster than any determined for the last 10,000 years.
- These changes in temperature are projected to be accompanied by an increase in sea level of 6 to 38 inches by 2100.
- The atmospheric lifetime of many greenhouse gases, coupled with the thermal inertia of the oceans, means that the warming effect of anthropogenic emissions will be long-lived—even sharp reductions in greenhouse gas emissions would reverse warming only slowly.

Ecological and Socioeconomic Systems

- Regional and global changes in temperature, precipitation, soil moisture, and sea level from climate change add important new stresses on ecological and socioeconomic systems that are already affected by pollution, increasing resource extraction, and nonsustainable management practices.
- Most systems are sensitive to both the rate and magnitude of climate change.
- Projected changes in climate will result in adverse effects on human health (particularly via vector-borne diseases) and many ecological systems (especially forests) and socioeconomic sectors (e.g., the regional production of food).
- Developing countries would be particularly vulnerable to these impacts.

Adaptation and Mitigation

- Stabilization of atmospheric concentrations of carbon dioxide at three times the pre-industrial concentrations or less will eventually require global emissions to drop below today's levels.
- A range of cost-effective technologies and policies can be used in both

developed and developing countries to markedly reduce the emissions of greenhouse gases from industrial, energy supply, energy demand, and land management practices.

- Deep long-term cost-effective reductions will require an intensive R&D program in energy, industrial, and crop technologies.
- Flexible, cost-effective policies relying on economic incentives and instruments, as well as internationally coordinated instruments, can considerably reduce mitigation and adaptation costs.
- Potential adaptation options for many developing countries are extremely constrained due to the limited availability of technological and economic options.
- International and intergenerational equity issues are critical for policy formulation.
- There is justification for going beyond a "no-regrets" action strategy. "No-regrets" actions are those that save money or achieve other environmental goals while also reducing greenhouse gas emissions.

CONDITIONS AND TRENDS

The Climate System

A natural "greenhouse effect" keeps the Earth about 33^{o} C (nearly 60^{o} F) warmer than it would otherwise be. Water vapor, carbon dioxide, and other gases trap heat as it is radiated from the Earth's surface back to space—much as the glass panels of a greenhouse trap heat inside. Without this natural greenhouse effect, life as we know it would not be possible.

Over the entire history of the planet, global climate has varied substantially. During the last ice age, which ended roughly 17,000 years ago, the Earth was an average of 9^{o} F cooler, and much of North America was covered in several thousand meters of ice. As the Earth warmed over the next 10,000 years, the glacial ice melted back and sea levels rose approximately 3 feet per century, among other things flooding our continental shelves and shallow estuaries like the Chesapeake Bay. As human society evolved, it adapted to regional climates and to slow shifts in natural variations.

As a result of global industrialization and the spread of agriculture over the past 200 years, human activities have added to the natural greenhouse effect by releasing additional greenhouse gases to the atmosphere. Carbon dioxide (CO_2) from burning fossil fuels is the primary source of emissions. Since plants and soils store large amounts of carbon, clearing forests for agriculture and other uses also contributes a significant share. Other greenhouse gases include methane (CH_4) and nitrous oxide (N_2O), as well as chlorofluorocarbons and their substitutes (see Chapter 11, "Stratospheric Ozone," for a discussion of the impact of chlorofluorocarbons on stratospheric ozone). The resulting buildup of greenhouse gases in the atmosphere is enhancing the natural greenhouse effect.

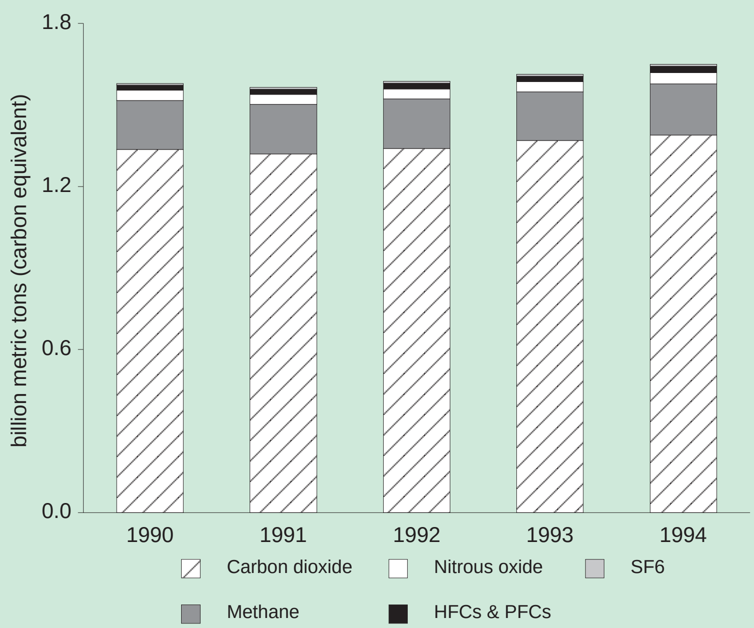
Emissions Trends

Since the preindustrial era, atmospheric concentrations of carbon dioxide have increased by nearly 30 percent, methane concentrations have doubled, and nitrous oxide concentrations have risen by 15 percent. Since 1958, carbon dioxide concentrations have increased by approximately 12 percent.

Figure 12.1 illustrates recent trends in U.S. emissions of greenhouse gases, which include carbon dioxide, methane, nitrous oxide, and various halogenated compounds. These contributions were calculated on the basis of each gas's potential to increase the greenhouse effect—its global warming potential (Box 12.1). Changes in CO_2 emissions from fossil fuel consumption had the greatest impact on total U.S. greenhouse gas emissions from 1990 to 1994. By 1994, CO_2 emissions from fossil fuels were 4 percent above 1990 levels. Emissions have risen with economic growth and falling energy prices.

Although the heat-trapping abilities of methane and nitrous oxide are relatively high, CO_2 has accounted for 65 percent of the increased radiation caused by greenhouse gases over the past 100 years. Carbon dioxide is released primarily from the combustion of fossil fuels and deforestation. According to the Department of Energy, approximately 85 percent of U.S. primary energy is produced from the

Figure 12.1 U.S. Emissions of Greenhouse Gases, 1990-1994



Source: See Part III, Table 28.
Notes: HFCs=hydrofluorocarbons. PFCs=perfluorocarbons. SF6=sulfur hexafluoride. Sinks not included.

Box 12.1
Global Warming Potential

Since some greenhouse gases trap more heat in the atmosphere than others, measurements of global warming potential have been developed to allow scientists and policymakers to compare the ability of greenhouse gases to trap heat in the atmosphere over time. Although any time period may be selected, the average warming over a 100-year period is recommended by the IPCC and is used in this report. Carbon dioxide is often used as a reference gas, and units are often millions of metric tons of carbon equivalent.

Over a 100-year period, methane is 24.5 times as effective as carbon dioxide at trapping heat in the atmosphere. In 1990, methane emissions were 27.1 million metric tons. However, their contribution to the greenhouse effect was equal to 181 million metric tons of carbon dioxide emissions.

Some human-induced gases that influence the climate system—such as sulfates and aerosols—actually have a cooling effect. However, aerosols are short-lived and vary regionally, and therefore they should not be counted as a simple offset to greenhouse gases. In addition, their buildup will likely be limited because of their health effects.

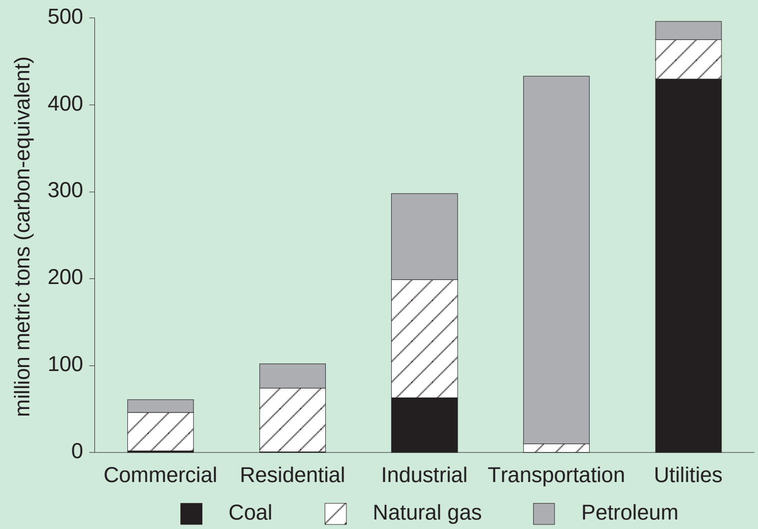
combustion of fossil fuels, and this combustion accounts for roughly 88 percent of annual emissions of all U.S. greenhouse gases on a carbon-equivalent basis. Petroleum supplies just over 38 percent of national energy needs, and natural gas and coal supply 25 and 22 percent, respectively. The amount of CO_2 produced in burning varies significantly across fuels. For example, coal has the greatest amount of carbon per unit of energy, followed by petroleum (about 25 percent less) and natural gas (about 45 percent less).

In the United States, it is estimated that electric utilities account for 36 percent of annual CO_2 emissions; coal supplies 55 percent of their energy requirements. Transportation (32 percent) is the second largest and fastest growing source of CO_2. Nearly two thirds of transportation emissions are the result of gasoline consumption. Industry (21 percent) relies on gas, oil, and coal. The residential (7 percent) and commercial (4 percent) sectors rely mainly on natural gas (Figure 12.2).

Carbon dioxide is absorbed by the oceans, trees, and soils and is emitted through natural processes. Forests cover about 737 million acres of the United States and absorb and store CO_2. Atmospheric concentrations of CO_2 are thus affected by changes in agricultural and forestry practices. From 1990 to 1992, U.S. forests, soils, and wood products sequestered approximately 125 million metric tons of carbon equivalent each year (see Chapter 17, "Forestry").

Methane is second only to CO_2 as a source of the enhanced greenhouse effect. Atmospheric methane concentrations have more than doubled in the last two centuries. Although methane is released by many natural processes (including the decay of organic matter),

Figure 12.2 U.S. Emissions of Carbon Dioxide from Fossil Fuel Combustion by Sector and Fuel Type, 1994



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1994* (EPA, Washington, DC, 1995).

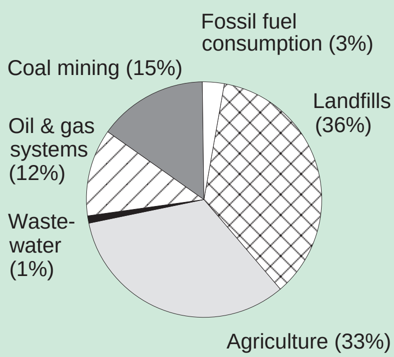
Note: Although not shown, U.S. territories account for slightly less than 1% of total emissions.

the increased atmospheric concentration is mostly due to human activities. The largest sources of U.S. methane emissions are landfills, agriculture, coal mining, and the production and processing of petroleum (Figure 12.3).

Nitrous oxide is approximately 320 times more heat absorbent than CO_2, although nitrous oxide emissions are much smaller by volume. Nitrous oxide is produced naturally from a wide variety of biological sources in soil and water. The use of fertilizer represented 45 percent of U.S. emissions in 1994. Manure, fossil fuel combustion, burning crop residues, and production of adipic and nitric acids also generate nitrous oxide emissions.

Halogenated compounds were first emitted to the atmosphere early this century. This family of engineered compounds includes chlorofluorocarbons (CFCs), partially halogenated compounds (HFCs and HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Industrial processes and consumer products that employ these substances include refrigeration and air-conditioning, solvent cleaning, and foam production. HFCs and PFCs were recently introduced as alternatives to CFCs, which are being phased out under the 1987 Montreal Protocol on Substances That Deplete the Ozone Layer. HFCs, PFCs, and SF_6 are all powerful green-

Figure 12.3 Sources of U.S. Methane Emissions, 1994



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1994* (EPA, Washington, DC, 1995).

house gases whose manufacture and emissions are expected to rise.

Climate Trends

The surface temperature this century is as warm as, or warmer than, that of any other century since at least 1400 A.D. Global temperatures do, in fact, appear to be rising. According to the IPCC, land-based observations as well as data collected from ships show that the Earth's average surface temperature has warmed 0.5^{o} to 1.0^{o} F in the last century. Although satellite observations provide only a 16-year series, too short to infer a trend, these data show the same pattern over land masses as the surface temperature measurements. The observed warming is consistent with what climate models calculate should have occurred due to the combined effects of greenhouse gases, depletion of the stratospheric ozone layer, and sulfate aerosols.

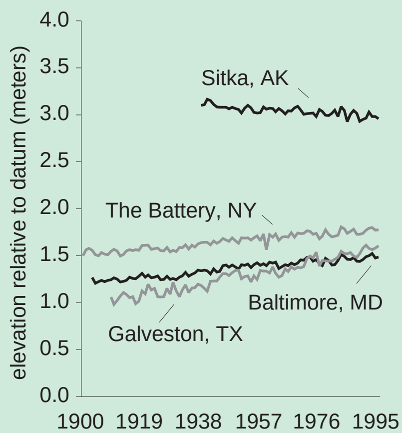
Temperature trends in the United States are also generally consistent with the climate model projections. The western states have been warming more rapidly than the global average. In the eastern states, however, where sulfates would be expected to have the greatest cooling effect, temperatures have cooled slightly in the last 50 years. U.S. nighttime temperatures are rising more rapidly than daytime temperatures.

Rainfall is tending to be more concentrated in heavy downpours, according to a new study by the National Oceanic and Atmospheric Administration. At the beginning of the 20th century, only 8 percent of the nation experienced a storm each year in which more than 2 inches of rain fell in a 24-hour period. In recent decades, such a severe storm occurs each year over about 12 percent of the nation.

Sea level is rising along the U.S. coast in all but a few northern areas, where the Earth's crust has been rising since the glaciers retreated at the end of the last ice age (Figure 12.4). The majority of U.S. shorelines are eroding, owing to sea level rise and other factors. In Maryland alone, for example, 30 miles of natural shoreline each year are replaced by rock revetments. Sea level has risen about 4-10 inches over the past century; about half of the rise is believed due to oceanic warming and half due to melting mountain glaciers.

Unless the world takes steps to reduce the emissions of carbon dioxide, the IPCC estimates that concentrations of atmospheric carbon dioxide will roughly double by 2100. Model calculations project that the average global surface tem-

Figure 12.4 Sea Level Trends Along the U.S. Coast, 1900-1995



Source: NOAA, Tide Station Data, unpublished, 1996.
Note: Data refer to yearly mean sea level values relative to tide station datum at each location.

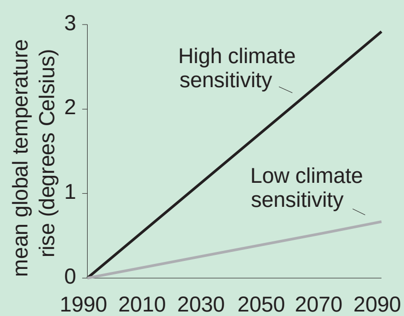
peratures will rise by about 1.8^{o} to 6.3^{o} F by 2100. Global average temperature changes of this magnitude would be greater than recent natural fluctuations and would occur at a rate significantly faster than has occurred over the last 10,000 years (Figure 12.5).

Based on these calculations, sea level is projected to rise by 6 to 38 inches by 2100, continuing the trend of thermal expansion of the oceans and glacial melting. Rising global temperatures are generally expected to increase the rate of evaporation and to lead to changes in precipitation and soil moisture. The models also suggest that the frequency of intense rainfall will increase and there will be a marked decrease in soil moisture over some mid-latitude continental regions during the summer. Such changes could have adverse effects on agriculture, forests, human health, and coastal communities.

Although it is unclear whether climate will become more variable, the frequency and intensity of some extreme weather events of critical importance to ecological systems (e.g., droughts, floods, frosts, frequent hot or cold spells, and associated fire and pest outbreaks) could increase with a global rise in temperature. Climate change cannot be unambiguously related to specific weather events; however, when they do occur, these events can be costly. For example, weather-related disasters since 1992 have resulted in $70 billion in damage and several hundred deaths from floods, heat waves, hurricanes, blizzards, and hailstorms.

The relatively long atmospheric residence times of many greenhouse gases—typically decades to centuries—coupled with the thermal inertia of the oceans, mean that the warming effect of human-induced emissions will be long-lived. Even with a stabilization of atmospheric

Figure 12.5 Alternative Global Temperature Rise Estimates*



Source: Intergovernmental Panel on ClimateChange, *Summary for Policy Makers* (Washington, DC, 1995).
Note: *Projections based on rising CO2 concentrations.

greenhouse gas concentrations in 2100, temperatures would continue to increase for several decades, and sea level would continue to rise for centuries. Although much is already known about the greenhouse effect and the basic heat-trapping property of the gases is essentially undisputed, substantial reduction in key uncertainties (detailed quantification of timing, magnitude, and regional patterns of change) may require a decade or more.

DIRECT IMPACTS AND SOCIAL RESPONSES

The regional and global impacts from human-induced climate change could add significant new stresses on ecological systems that are already affected by pollution, increasing resource extraction, and unsustainable management practices. The most vulnerable systems are those with the greatest sensitivity and the least adaptability. To varying degrees, natural ecosystems, socioeconomic systems, and human health are sensitive to both the rate and the magnitude of climate change. Further, developing countries—which have historically had the lowest emissions—are generally more vulnerable to climate change than industrialized nations because of their geographic, socioeconomic, and cultural conditions, according to the IPCC.

Rising global temperatures are expected to raise sea level and change precipitation and other local climate conditions. Changing climate could alter crop yields, water supplies, and the composition of forest species and threaten human health, air and water quality, and some forests and other ecosystems.

Human Health. Throughout the world, the prevalence of particular diseases and other threats to human health depends partly on local climate. Insects and other pests that carry diseases are often limited by climate. For example, the parasite that causes malaria cannot develop at temperatures below 57° to 61° F. Heat itself can threaten human health. In July 1995, for example, a 5-day heat wave contributed to the deaths of more than 400 people in Chicago alone.

The most direct effect of changing climate on human health is heat stress. Statistics on mortality and hospital admissions show that death rates increase during extremely hot days, particularly among very old and very young people living in cities. The indirect effects of climate change, however, could be more serious. The potential transmission of diseases spread by mosquitoes and other insects, for example, could increase as warmer temperatures enable the cold-blooded insects to survive farther north, at higher altitudes, or for longer seasons. Other pest-borne diseases that may become more severe include malaria, dengue fever, yellow fever, and encephalitis. Climate change may also cause outbreaks of diarrheal diseases, such as cholera. It could also promote toxic algal blooms, which are often associated with contaminated seafood.

Although climate change could increase malaria by as many as 50-80 million cases a year, according to the IPCC, existing public health resources would make a reemergence of this disease in the United States very unlikely. Similarly, heat-related deaths can be reduced by accurate warning systems, appropriate emergency response measures (e.g., moving vulnerable people to air-conditioned buildings), and behavioral changes on the part of individuals (e.g., curtailing physical activities, drinking fluids). Other impacts of climate change on health could be minimized through maintenance of strong public health programs to monitor, quarantine, and treat the spread of infectious diseases. However, these measures may be costly to implement and developing countries may not have the infrastructure to cope with these health-related impacts.

The American Public Health Association (APHA) recently adopted a resolution expressing concern about the human health effects of climate change. In view of the scale of potential impacts, the APHA recommended precautionary primary preventative measures (e.g., reductions in greenhouse gases) to avert climate change.

Water Resources. Precipitation and evaporation are both likely to increase worldwide. In those areas where evaporation increases more than precipitation, soil will become drier, lake levels will drop, and rivers will carry less water.

Lower river flows and lake levels could impair navigation and water quality and reduce the amount of water available for ecological, agricultural, residential, and industrial uses, as well as for hydropower. Some areas may experience both increased flooding during winter and spring and lower supplies during summer. In California's Central Valley, for example, melting snow provides much of the summer water supply; warmer temperatures would cause the snow to melt earlier and thus reduce summer supplies even if rainfall increased during the spring. More generally, the tendency for rainfall to be more concentrated in large storms as temperatures rise would tend to increase river flooding, without increasing the annual amount of water available.

Many federal and state agencies are actively engaged in reducing the nation's vulnerability to these types of impacts. In the western United States, where freshwater is scarce, a trend toward allowing farmers to sell water is enabling scarce water to be used more efficiently. Along the Mississippi River and other flood plains, the Federal Emergency Management Agency and others are reviewing structural and land use measures for reducing vulnerability to floods. Finally, both the Corps of Engineers and the Bureau of Reclamation are developing better ways to manage the federal system of reservoirs in the face of changing climate to meet the competing needs of navigation, hydropower, water supply, recreation, and environmental quality.

Coastal Zones. Sea level is rising more rapidly along some U.S. coasts than worldwide. A 1995 study by EPA estimates that along the Gulf and Atlantic coasts, a 1-foot rise in sea level is likely by 2050 and could occur as soon as 2025. Such a rise would cause most sandy beaches to erode 100 to 200 feet. In undeveloped areas, beaches and wetlands would simply migrate inland. Along developed coasts, however, homes are often less than 100 feet from the water's edge. Thus, even a 1-foot rise in sea level would require many ocean beach resorts to incur the costs of periodically pumping sand onto their beach or removing beachfront houses.

Over the longer term, a 1.5- to 3-foot rise in sea level could inundate up to one half of U.S. coastal wetlands and 4,000 to 7,000 square miles of dry land, if developed areas were not adequately protected with bulkheads or other structures. Most of these losses would be concentrated in the southeastern and mid-Atlantic states, particularly Louisiana and Florida. If bulkheads are built to protect developed areas, the loss of dry land will be less, but the wetlands and beaches would be lost if the structures are built and block their landward migration.

To protect the coastal environment and the public's right to use the shore, several states have adopted policies to ensure that beaches, dunes, or wetlands are able to migrate inland as sea level rises. Some states prohibit new houses in areas likely to be eroded in the next 30 to 60 years. Concerned about the need to protect property rights, Maine, South Carolina, and Texas have implemented some version of "rolling easements," in which people are allowed to build, but only on the condition that they will remove the structure if and when it is threatened by an advancing shoreline.

Agriculture. The success or failure of a harvest has always depended on climate, with the most important factor being a sufficiently moist soil during the growing season. During extended droughts such as the Dust Bowl of the 1930s, crop failures have been widespread. Some climatologists suggest that such conditions could become even more widespread because of the drier soils that may accompany changing climate. Increased heat stress, more frequent flooding, and salinization of soils due to sea level rise could also threaten agriculture in some areas.

There may also be some offsetting benefits to agriculture. In colder areas, warmer temperatures would lengthen the growing season. Moreover, higher levels of atmospheric carbon dioxide have a fertilizing effect, which enables plants to grow more rapidly. Finally, up to a certain concentration higher carbon dioxide levels also increase the efficiency with which plants use water, which may tend to offset some of the adverse effects of drier soils.

Recent assessments of the impact of climate change on agriculture have suggested that the beneficial effects would offset the adverse impacts, at least in the United States. A 1995 study by USDA, for example, concluded that even a 5^{o} to 9^{o} F warming would be unlikely to significantly affect total U.S. agricultural production.

Nevertheless, there may be significant dislocations. Several studies have suggested that Appalachian farmers could be particularly vulnerable. Other, drier areas could become permanently lost to agriculture or require expensive irrigation.

Forests and Terrestrial Ecosystems. A 3.6^{o} F warming could shift the ideal range for many North American forest species by about 200 miles to the north. If the climate changed slowly enough, warmer temperatures would enable the individual species to migrate north into areas that were previously too cold, at about the same rate as southern areas became too hot for the species to survive. If Earth warms 3.6^{o} F in 100 years, however, the species would have to migrate 2 miles per year, which is much faster than most tree species are able to migrate.

Several other impacts associated with changing climate further complicate the picture. On the positive side, it is possible that the fertilization effect of carbon dioxide on plants may enable some species to resist the adverse effects of warmer temperatures or drier soils (as long as nutrients are not limiting). Nevertheless, increased severity of fires and droughts, or changes in pest populations, could further increase the stress on forests. Managed forests may tend to be less vulnerable than unmanaged forests, because the managers will be able to shift to tree species appropriate for the warmer climate.

The potential impacts of climate change on wildlife are poorly understood. If habitats simply shift to higher latitudes or higher altitudes, many forms of wildlife could potentially adapt to climate change, although the complete ecosystem on which they depend may not be able to move in tandem. Unlike previous climatic shifts, roads, development, and other modifications to the natural environment may block the migration routes. Moreover, the rate of climate change is predicted to be far faster than has occurred in the past, further limiting natural adaptation. For example, nature reserves, often established to protect particular species, may no longer be located in a climate hospitable to that species.

Impact on Other Forms of Pollution. Changing climate will have ramifications for efforts to protect the environment described in other chapters of this report, particularly air and water pollution efforts. In those areas where river flows decline, water could become more polluted because there would be less freshwater to dilute existing effluents. Even in areas where river flows are maintained, warmer temperatures would tend to lower the level of dissolved oxygen, threatening the ability of several southern states to attain their water quality criteria standards. Increasing amounts of rainfall during severe storms would increase the frequency with which combined municipal wastewater systems are overwhelmed, necessitating more discharges of raw sewage; more severe storms would also increase nonpoint pollution runoff.

Changing climate could also impair urban air quality. For example, warmer temperatures enhance the process of photochemical oxidation and would thus be likely to increase ozone levels in metropolitan areas.

RECENT POLICY DEVELOPMENTS

The Climate Change Action Plan

In 1992, as part of the Earth Summit in Rio de Janeiro, the United States joined with more than 150 other nations in signing the Framework Convention on

Climate Change. This landmark treaty called for cooperation among all nations in addressing the risks of climate change and established as a non-binding aim that developed countries seek to return their greenhouse gas emissions to 1990 levels by the year 2000.

On Earth Day in 1993, President Clinton announced the U.S. program to meet this goal. The Climate Change Action Plan included almost 50 largely voluntary measures aimed at reducing net greenhouse gas emissions while saving industry and the public billions of dollars in reduced energy costs. The plan relied extensively on innovative public-private partnerships to encourage development and enhanced diffusion of energy- and cost-saving technologies (Box 12.2). The original goals outlined in the plan called for reductions in emissions of over 100 million metric tons of carbon equivalent (roughly 8 percent below baseline growth). These reductions would be achieved at an estimated cumulative savings of $61 billion to the U.S. economy between 1990 and 2000.

In the two years since the Plan was announced, considerable progress has been made in implementing many of the actions. For example, the Climate Challenge program has attracted participation by utilities representing over half of the Nation's electricity production. These companies have agreed to undertake a wide range of activities aimed at reducing net greenhouse gas emissions (Box 12.3).

Other actions have facilitated the increased market diffusion of energy efficient lighting through the Green Lights programs (Box 12.4) and the use of energy-saving office computers, printers, and other office equipment through Energy Star products (Box 12.5).

Box 12.2
Highlights of the Climate Change Action Plan

The Clinton Administration's Climate Change Action Plan:

- **Identifies and promotes the use of energy-efficient products.** The plan provides opportunities for corporate purchasers and consumers to make educated decisions on energy use.
- **Promotes large-scale purchasing of energy-efficient and renewable technologies.** By helping to improve economies of scale and by moving these technologies into the market, the plan helps prices fall to levels equal to or below those of alternatives that result in higher greenhouse gas emissions.
- **Encourages industry to commercialize more resource-efficient technologies.** The plan demonstrates that these technologies will sell by providing clear "market-pull" that is organized through mass-purchase initiatives and program coordination.
- **Promotes sensible regulatory and legal frameworks.** The plan encourages cost-effective investments in energy efficiency and methane recovery programs.

Box 12.3
Emissions Reductions by Electric Utilities—Climate Challenge

"In the global warming debate, proactive management, willingness to negotiate and leadership through voluntary initiatives are our strongest trump cards. . . Through a series of positive actions, we can become participants in positive progress instead of negative rule."

Mark DeMichele, President and CEO, Arizona Public Service

"This voluntary, flexible initiative is the best way to tap the utility industry's technical skill and problem solving capabilities, while obviating the need for costly command and control requirements."

E. Linn Draper, Jr., Chairman, American Electric Power

Despite the substantial success of actions under the Plan, it now appears likely that the U.S. will fall far short of the original goal of returning net greenhouse gas emissions to 1990 levels by the year 2000. Actions under the Plan have been scaled back due to significant budget reductions and policy restrictions that have been imposed by Congress over the past several years. In addition, stronger-than-expected economic growth and lower-than-expected energy prices have pushed energy use higher, thus requiring greater reductions than initially called for in the Plan to achieve stabilization at 1990 levels.

In related activities, the Clinton Administration has started several initiatives that would help to substantially reduce greenhouse gas emissions over the period beyond 2000. For example, the Administration has joined with automobile manufacturers and suppliers in the United States in a research and developmnent program called the Partnership for a New Generation Vehicle. The program's goal is the development of technological and manufacturing breakthroughs that would lead to a car with three times

Box 12.4
EPA's Green Lights Program

EPA's Green Lights program encourages commercial businesses and government agencies to reduce their lighting energy consumption by introducing them to the economic and environmental benefits of investing in energy-efficient lighting technology.

The program has partnered with over 2,000 participants committed to upgrading the lighting in over 5 billion square feet of commercial, manufacturing, retail, and government facilities nationwide (the equivalent of 1 out of every 14 commercial buildings). Green Lights partners have already upgraded over 1 billion square feet of office space.

In 1995, the Green Lights program prevented the emission of over 3 billion pounds of carbon dioxide and saved over 2 billion kilowatt-hours of electricity, leading to $200 million in savings for program partners.

Box 12.5
EPA's Natural Gas STAR Program

EPA's Natural Gas STAR Program is a voluntary program that works closely with the natural gas industry to reduce leaks and losses of methane (the primary component of natural gas). The program consists of two initiatives, one focused on the transmission and distribution sectors, and the other concentrating on the production and processing sectors. EPA provides support for partners by providing public recognition and technical expertise on new technologies. Working with EPA regional offices and state agencies, the program has been successful in removing many state barriers that prevent the use of pollution prevention as a method for reducing emissions.

By encouraging companies to adopte cost-effective best management practices that reduce leaks and losses of natural gas, Natural Gas STAR promotes innovative processes and technologies that save companies money, save natural gas resources, and reduce greenhouse gas emissions. Partners of the program currently represent 62 percent of transmission company pipeline mileage, 30 percent of distribution company pipeline mileage, and 25 percent of U.S. natural gas production.

In 1995, the Natural Gas STAR Program reduced emissions by over 4 billion cubic feet, equivalent to over 3 billion pounds of carbon dioxide. This is enough gas to heat 55,000 homes per year. The greenhouse gas impact was equivalent to removing 250,000 cars from the roads. Program partners saved about $8 million in 1995.

the fuel efficiency of current models without sacrificing cost, comfort, or safety.

Substantial energy savings and greenhouse gas reductions also appear possible in the buildings sector. The Building and Construction Initiative aims to improve the competitive performance of this $800 billion industry by developing better construction technologies through reducing waste and pollution as well as through improved performance, comfort, cost, safety, and durability.

The Administration's Environmental Technology Initiative represents another opportunity to encourage private sector efforts to develop and disseminate superior environmental technologies, including those that reduce greenhouse gas emissions. Overall, environmental technologies represent an estimated market of $180 billion in the United States and support more than 1.2 million jobs. Global markets are estimated at 3-4 times the U.S. market. This market opportunity represents one of the most promising opportunities for growth in sustainable, high-paying jobs.

Finally, given the need to involve all nations in reducing the risks of climate change, the United States has initiated a number of programs to encourage actions by developing countries to reduce their emissions of greenhouse gases. Under the 1992 climate convention, all nations (including developing nations) are required to prepare inventories of their emissions of greenhouse gases and to adopt measures aimed at addressing climate change.

To encourage sustainable development, and to demonstrate the potential effectiveness of "joint implementation" activities (e.g., projects where technology is transferred to and reductions are achieved in developing countries) under the convention, the U.S. has engaged in an active program with a number of developing countries (Box 12.6).

Box 12.6

Country Studies Program and the U.S. Initiative on Joint Implementation

The United States continues to look for cost-effective means to reduce emissions of greenhouse gases internationally. The Action Plan encourages U.S. businesses to develop economic opportunities for international greenhouse gas emissions reductions through the U.S. Initiative on Joint Implementation (USIJI). A pilot program, USIJI encourages organizations in the United States to implement projects internationally that reduce, avoid, or sequester greenhouse gases. Since its launch in 1993, this interagency program has become the largest effort worldwide to explore options for countries to jointly reduce greenhouse gases. In addition, the Countries Studies Program provides financial and technical support to some 55 developing countries and countries with economies in transition to help them better understand their greenhouse gas emissions, potential impacts from climate change, and opportunities for emissions reductions.

Next Steps

Climate change represents one of the most complex problems facing our society. Scientific knowledge has improved dramatically, as reported in the latest IPCC assessment. Nonetheless, many uncertainties remain concerning the exact timing, magnitude, and regional impacts of climate change. Continued research through the U.S. Global Change Research Program (Box 12.7) and the international assessment process is needed to improve our understanding of the rate and magnitude of future climate change.

This is not a problem that any one country or even the developed countries acting in concert can solve. All nations must join together in developing a response to climate change.

The critical next point in that process involves negotiations underway to strengthen the Climate Convention agreed to in 1992. These negotiations are scheduled to conclude at the Third Conference of the Parties in December 1997.

At a recent negotiating session in July 1996, the United States proposed a new framework for the Convention. The U.S. rejected proposals by other countries calling for significant near-term reductions and for inflexible harmonized policies and measures. Instead, the U.S. called for realistic, verifiable, legally binding medium-term targets utilizing flexible approaches. The United States also called on all nations, including developing nations, to take actions to limit their emissions of greenhouse gases.

Box 12.7
The U.S. Global Change Research Program

The U.S. Global Change Research Program (USGCRP) was established in 1989 in recognition of the importance of a strong research base for understanding, predicting, and assessing global environmental changes, such as ozone depletion and climate change, their regional impacts, and their consequences for human health, food production, ecological systems, and sustainable economic development.

The USGCRP coordinates the global change research activities of 15 departments and agencies of the U.S. government. It is the largest coordinated environmental R&D effort under the auspices of the National Science and Technology Council. The USGCRP will invest approximately $1.7 billion in climate change research during 1997. All U.S. Government climate change research is carried out as part of the USGCRP, and the findings from USGCRP-sponsored research have been important contributions to the Intergovernmental Panel on Climate Change science assessments and have assisted U.S. decision-making on climate issues.

The objectives of the USGCRP are to: (1) observe and document changes in the Earth system; (2) understand what changes are occurring and why; (3) improve predictions of future global change; (4) analyze the environmental, socioeconomic, and health consequences of global change; and (5) support state-of-the-science assessments of global environmental change issues.

In support of these general objectives, the program is focused on four key, inter-linked science issues:

- Seasonal to interannual climate variability, with the goal of obtaining a predictive understanding and the skills to produce forecasts of short-term climate fluctuations and to apply these predictions to social and economic development in the United States and abroad.
- Climate change over decades to centuries, with the goal of understanding, predicting, assessing, and preparing for changes in the climate and the global environment resulting from projected changes in population, energy use, land cover, and other natural and human-induced factors.
- Changes in ozone, UV radiation, and atmospheric chemistry, with the goal of understanding and characterizing the chemical changes in the global atmosphere and their consequences for human and ecological health and well-being.
- Changes in land cover and in terrestrial and marine ecosystems, with the goal of providing a stronger scientific basis for understanding, predicting, assessing, and responsing to the causes and consequences of ecosystem change resulting from human-induced and natural influences.

Participants in the program include the Agriculture, Commerce (the National Oceanic and Atmospheric Administration and National Institute of Standards and Technology), Defense, Energy, Health and Human Services (the National Institute of Environmental Health Sciences), Interior, Transportation, and State departments, as well as the Environmental Protection Agency, the National Aeronautics and Space Administration, the Smithsonian Institution, the Tennessee Valley Authority, the Office of Science and Technology Policy, the Office of Management and Budget, the Council of Economic Advisers, and the intelligence community.

The approach proposed by the United States was widely accepted by other nations and was incorporated into the Geneva Declaration that was adopted as a Ministerial Statement by most nations at the meeting.

The rationale for the U.S. position is threefold. First, the 1995 IPCC report has reinforced the strong concerns about the likelihood and implications of climate change, as well as the role of human activities. Second, the existing framework of nonbinding national targets is unlikely to achieve expected results. Third, clear, realistic, and agreed-upon objectives are needed to ensure that all nations will honor their commitments to reduce emissions both for environmental and for competitiveness reasons.

The United States is working through the multilateral negotiations to reach agreement on a verifiable and binding medium-term emissions target in time for the next Conference of the Parties in December 1997. The following principles will guide the Administration in these discussions: environmental protection, realism and achievability, economic prosperity, flexibility, fairness, and comprehensiveness.

Specifically, the Administration believes any medium-term target must be met through maximum flexibility in the selection of implementation measures, including the use of reliable joint implementation measures and emissions trading systems around the world. Any future commitment must ensure that the U.S. economy remains robust and internationally competitive and that early voluntary actions are recognized.

All countries—developed and developing—should take steps to limit emissions. While the developed countries have a responsibility to lead, this effort must be a partnership, with all nations contributing to the objective of the climate treaty.

The Administration is committed to continuing discussions with the public, Congress, industry, nongovernment organizations, and other experts on U.S. emissions trends and on strategies to reduce emissions in the next century. Scientific, economic, and technical analysis will continue to guide evaluation of the practicality of specific targets and options for achieving them.

President Clinton has urged all Americans to prepare for the economic challenges of the 21st century. While climate change is a serious long-term problem, progress must be made in the medium term by involving the public and private sectors. Sustained long-term investment and the creativity of the marketplace are required to develop and utilize the technologies that will ensure the nation's long-term environmental and economic prosperity.

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