U.S. CLIMATE ACTION REPORT—2006

Fourth National Communication of the United States of America
Under the United Nations Framework Convention on Climate Change

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1 Executive Summary

The United States is pursuing a comprehensive strategy to address global climate change that is science-based, fosters breakthroughs in clean energy technologies, and encourages coordinated global action in support of the United Nations Framework Convention on Climate Change (UNFCCC).

The U.S. strategy integrates measures to address climate change into a broader agenda that promotes energy security, pollution reduction, and sustainable economic development. This integrated approach recognizes that actions to address climate change, including actions to mitigate greenhouse gas (GHG) emissions, will be more sustainable and successful if they produce multiple economic and environmental benefits.

The United States is committed to continued leadership on climate change. Promoting biofuels, advanced fossil fuel technologies, renewable sources of energy, and advanced nuclear technologies is a key component of U.S. climate-related efforts. Since 2001, the Nation has dedicated nearly $29 billion to advance climate-related science, technology, international assistance, and incentive programs.

In 2002, President Bush announced plans to cut GHG intensity—emissions per unit of economic activity—by 18 percent by 2012. The Nation is on track to meet this goal. Dozens of federal programs, including partnerships, consumer information campaigns, incentives, and mandatory regulations, combined with state and local efforts, contribute to the ultimate objective of the UNFCCC: stabilizing atmospheric GHG concentrations at a level that would prevent dangerous human interference with the climate system. These coordinated actions are advancing the development and market uptake of cleaner, more efficient energy technologies, conservation, biological and geological sequestration, and adaptation to climate risks.

Recognizing the serious, long-term challenges of global climate change, the United States continues to work with nations around the world. Active bilateral and multilateral climate change initiatives, including the recently established Asia-Pacific Partnership on Clean Development and Climate, are promoting collaboration among key countries and with the private sector.

In this *U.S. Climate Action Report* (2006 CAR), the United States provides its fourth formal national communication under the UNFCCC, as specified under Articles 4 and 12 of the Convention. The 2006 CAR documents the climate change actions the Nation is taking to help achieve the UNFCCC's ultimate objective. This review was undertaken to account for activities up to and including 2006. It explains how U.S. social, economic, and geographic circumstances affect U.S. GHG emissions; summarizes U.S. GHG emission trends from 1990 through 2004; identifies existing and planned U.S. policies and measures to reduce GHGs; indicates future trends for U.S. GHG emissions; outlines impacts and adaptation measures; provides information on financial resources and technology transfer; details U.S. research and systematic observation efforts; and describes U.S. climate education, training, and outreach initiatives.

NATIONAL CIRCUMSTANCES

Chapter 2 of this report outlines the national circumstances of the United States and how those circumstances affect U.S. GHG emissions. The United States is a vast and prosperous country with diverse topography, biota, climates, and land uses. The U.S. economy is large and vibrant, driven by a growing and geographically dispersed population. The United States has the highest real gross domestic product (GDP) in the world. U.S. GDP has experienced significant growth since 2000; by 2005 it increased by 13.4 percent to slightly over $11.1 trillion (in constant 2000 dollars). The United States is the third most populous country in the world; from 2000 to 2005, the U.S. population grew by about 1 percent per year. In 2005, the U.S. population was an estimated 296.4 million people, an increase of about 15 million people since 2000, of whom 42 percent are immigrants.

The diversity of climate zones found throughout the United States results in both regional differences in energy use and impacts associated with climate change and variability. The United States possesses a broad mix of energy resources to produce power and meet other energy requirements. Petroleum remains the largest single source of energy consumed in the United States, accounting for 40 percent of total energy demand in 2005. Other major energy sources include natural gas at 23 percent, coal at 22 percent, nuclear at 8 percent, and renewables at 6 percent.

The United States has a highly developed transportation system that is designed to meet the needs of a mobile and dispersed population. This demand for mobility and the desire for larger and more affordable homes—along with other socioeconomic factors—are associated with the decentralizing trend observed in U.S. metropolitan areas. The sustained growth in new housing in the South and West, where most new homes have air conditioning, has increased residential electricity demand, as has the increase in housing size and the use of consumer electronics, such as computers and rechargeable tools.

These and other factors contribute to the United States being the world's largest producer and consumer of energy. Many of the long-term trends identified in the 2002 CAR continue today, but recent events have significantly affected U.S. national circumstances. In particular, the economic slowdown in 2001 and early 2002 had a major impact on energy use and, correspondingly, GHG emissions. As economic recovery took hold in 2002, energy demand also picked up, topping 100 quadrillion British thermal units in 2004. However, technological change, energy efficiency improvements in transportation, buildings, and other sectors, and a shift to less energy-intensive economic activity have continued to slow the growth of energy demand. As a result, while absolute energy use rose from 2000 to 2005, the amount of energy used per dollar of economic output—the energy intensity of the economy—fell by 11 percent.

GREENHOUSE GAS INVENTORY

Chapter 3 summarizes U.S. anthropogenic GHG emission trends from 1990 through 2004 (the most recent submission to the UNFCCC). The estimates presented in the report were calculated using methodologies consistent with those recommended by the Intergovernmental Panel on Climate Change (IPCC).

Although the direct GHGs—carbon dioxide, methane, and nitrous oxide—occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. In 2004, total U.S. GHG emissions were 7,074.4 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.). Overall, total U.S. emissions rose by 15.8 percent from 1990 through 2004. Over that same time period, U.S. GDP increased by 51 percent (U.S. DOC/BEA 2006a).

Carbon dioxide (CO_2) accounted for approximately 85 percent of total U.S. GHG emissions in 2004. As the largest source of U.S. GHG emissions, CO_2 from fossil fuel combustion has accounted for approximately 80 percent of global warming potential-weighted emissions since 1990. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 through 2004. The fundamental factors influencing this trend include (1) general domestic economic growth over the last 14 years, and (2) significant growth in emissions from transportation activities and electricity generation. Between 1990 and 2004, CO_2 emissions from fossil fuel combustion increased from 4,696.6 Tg CO_2 Eq. to 5,656.6 Tg CO_2 Eq., a 20 percent total increase over the 14-year period. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Methane (CH_4) accounted for 8 percent of total U.S. GHG emissions in 2004, with landfills being the largest anthropogenic source of CH_4 emissions. Overall, U.S. emissions of CH_4 declined by 10 percent from 1990 through 2004.

Nitrous oxide (N_2O) accounted for approximately 5 percent of total U.S. GHG emissions in 2004. The main U.S. anthropogenic activities producing N_2O are agricultural soil management and fuel combustion in motor vehicles. Overall, U.S. emissions of N_2O declined by 2 percent from 1990 to 2004.

Halogenated substances—hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—accounted for 2 percent of total U.S. GHG emissions in 2004. The increasing use of these compounds since 1995 as substitutes for ozone-depleting substances has been largely responsible for their upward emission trends.

POLICIES AND MEASURES

The U.S. approach to climate change combines near-term GHG mitigation programs with substantial investments in the transformational technologies needed for even greater emission reductions in the future. Chapter 4 of this report outlines near-term policies and measures undertaken by the U.S. government to mitigate GHG emissions.

Meeting President Bush's commitment to reduce the GHG intensity of the U.S. economy by 18 percent by 2012[1] will prevent the release of more than 1,833 Tg CO_2 Eq. to the atmosphere, adding to the 255 Tg CO_2 Eq. avoided in 2002. The President's emissions intensity approach ensures a focus on policies and measures that reduce emissions while fostering a growing, prosperous economy. Over the same period from 2002 to 2012, while GHG intensity is declining, total gross GHG emissions are expected to rise by 11 percent to more than 7,709 Tg CO_2 Eq.

The United States has implemented a range of programs that are contributing to the achievement of this 18 percent intensity goal—including regulatory mandates, tax and other incentives, consumer and education campaigns, and voluntary actions. This report details near-term federal climate programs and policies that span the major sectors of the U.S. economy encompassing generation and use of energy in the commercial, residential, industrial, and transportation sectors, and management of agriculture, forestry, waste streams, and industrial by-products. A number of new initiatives have been introduced since 2002, and many are already achieving significant emission reductions.

Additionally, several fiscal and incentive-based policies are mitigating emissions. The Energy Policy Act of 2005 contains new tax rules that are helping to unleash substantial new capital investment, including purchases of cleaner, more efficient equipment and facilities. The Act also grants the U.S. Department of Energy (DOE) the authority to issue loan guarantees for a variety of early commercial projects that use advanced technologies that avoid, reduce, or sequester GHGs. Further, it authorizes DOE to indemnify against certain regulatory and litigation delays for the first six new nuclear plants, and offers production tax credits for 6,000 megawatts of new nuclear capacity.

A number of U.S. states and cities are implementing a range of voluntary, incentive-based, and locally relevant mandatory measures. Many of these build on or partner with related federal programs and contribute to meeting the President's GHG intensity goal.

PROJECTED GREENHOUSE GAS EMISSIONS

Chapter 5 of the 2006 CAR provides estimates of projected national GHG emissions. These projections are used to measure the effectiveness of the emission reduction programs and progress toward achieving the targets established under the Global Climate Change policy announced by President Bush in February 2002. Based on the latest forecasts of CO_2 and non-CO_2 GHG emissions, which reflect current economic conditions and include the effects of federal climate programs, the United States is projected to exceed the President's goal of reducing GHG intensity by 18 percent from 2002 to 2012. In absolute terms, the intensity goal corresponds to a reduction in GHG emissions of 367 Tg CO_2 Eq. in 2012 and more than 1,833 Tg CO_2 Eq. in cumulative GHG reductions between 2002 and 2012, relative to projected emissions under *Business As Usual* conditions. From 2002 through 2012, GHG emissions are expected to rise by 11 percent to 7,709 Tg CO_2 Eq.

This chapter also contains inventory data for 2000 and emission projections to 2020 for the United States. These projections reflect national estimates of GHG emissions, considering population growth, long-term economic growth potential, historical rates of technology improvement, normal weather patterns, and reductions due to implemented policies and measures.

IMPACTS AND ADAPTATION

Chapter 6 of this report highlights actions taken in the United States to better understand and respond to vulnerabilities and impacts associated with climate change. The U.S. government has made considerable scientific progress in understanding the nature of climate change and its potential effects. It is involved in a wide array of climate assessments, research, and other activities to understand the potential impacts of climate change and climate variability on the environment and the economy, and to develop methods and tools to enhance adaptation options. Attention is also being focused at the local and state levels as well.

Chapter 6 also presents a selection of sector- and region-specific adaptation projects that illustrate the variety and scale of approaches used within the United States. These activities inform decision-making processes at all levels—local, national, and international—and help to increase societal resilience to climate changes.

Since 2002, U.S. research has led to new insights into the impacts of climate change and variability on key physical processes (e.g., snowpack, streamflow, extreme events) that have implications for a range of socioeconomic sectors. In addition to participation in national and international assessment processes, the United States is engaged in national efforts to reduce uncertainty regarding climate change impacts. The U.S. government is providing practical scientific information and tools to help decision makers plan for potential changes in climate. These activities address the Nation's needs for sound scientific information that decision makers can use to develop a better understanding of climate change impacts and vulnerabilities, as well as to improve the design and implementation of adaptation measures.

FINANCIAL RESOURCES AND TRANSFER OF TECHNOLOGY

Cooperation with other countries to address climate change continues to be a high priority for the United States. Chapter 7 outlines U.S. agency roles in international assistance and technology transfer. U.S. financial flows to developing and

[1] At the time this commitment was made in February 2002, U.S. GHG emissions intensity was expected to improve by 14 percent from 2002 to 2012 under a *Business As Usual* reference case. The President's goal, therefore, was expected to improve GHG intensity by 4 percentage points over the expected 14 percent.

transition economies that support the diffusion of climate-related technologies include official development assistance and official aid, government-based project financing, foundation grants, nongovernmental organization (NGO) resources, private-sector commercial sales, commercial lending, foreign direct investment, and private equity investment.

Adaptation to climate variability and change is an important component of U.S. financial and technical cooperation to address climate change. U.S. government agencies are involved in collaborative efforts to develop and support the many different scientific and technical activities needed to promote adaptation, including Earth observations, research and modeling, and pilot projects. A number of U.S. government agencies also provide financial resources and transfer of technology to address development and climate change. These programs apply a variety of approaches in locations around the globe. Capacity building and institution building are fundamental to the success and sustainability of these development efforts.

The United States provides substantial assistance resources through bilateral and multilateral avenues. Between 2001 and 2006, U.S. funding for climate change in developing countries totaled approximately $1.4 billion, including $209 million to the Global Environment Facility (GEF) in support of climate change projects (out of a total GEF contribution of approximately $680 million). The United States is the largest contributor to both the UNFCCC and multilateral development banks, the latter of which undertake a range of international energy investment and adaptation activities. Though these resources are a relatively small share of overall climate-related investment flows, they are important in promoting the policy and institutional environment necessary to generate recipient countries' investments in cleaner and more efficient technologies.

Since 2002, the United States has established and participated in a range of new international partnerships to contribute to the ultimate objective of the UNFCCC and promote sustainable development. These include the Asia-Pacific Partnership on Clean Development and Climate, the Methane to Markets Partnership, the Carbon Sequestration Leadership Forum, the International Partnership for a Hydrogen Economy, the Generation IV International Forum, the President's Initiative Against Illegal Logging, and the Group on Earth Observations. The United States also participates in the Renewable Energy and Energy Efficiency Partnership, the Global Bioenergy Partnership, and the Renewable Energy Policy Network for the 21st Century. Private-sector involvement is a key aspect of these partnerships, and each of the partnerships includes countries from all regions of the world, contributing to the development, deployment, and transfer of technology across the globe. Additionally, the United States has established bilateral climate partnerships, encompassing more than 450 individual activities, with 15 countries and regional organizations.

RESEARCH AND SYSTEMATIC OBSERVATION

Chapter 8 outlines how the United States is laying a strong scientific and technological foundation to reduce uncertainties, clarify risks and benefits, and develop effective mitigation options for climate change that complements U.S. efforts to slow the pace of growth of GHG emissions. In 2002, President Bush established a cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI), to provide guidance for investments in climate change science and technology, with funding of approximately $4.5 billion annually. CCCSTI coordinates two multi-agency programs—the Climate Change Science Program (CCSP), led by the U.S. Department of Commerce, and the Climate Change Technology Program (CCTP), led by DOE. These two coordinated programs address issues at the intersection of science and technology, such as the evaluation of approaches to sequestration, anthropogenic GHG emissions monitoring, global Earth observations, and energy technology development and market penetration scenarios.

The United States funds a significant portion of the world's climate change research. Climate change and climate variability play important roles in shaping the environment, infrastructure, economy, and other aspects of life in all countries, and decision makers must be able to make informed decisions regarding these changes. U.S. global change research and global observations are facilitating decision makers' access to better and more reliable information.

CCSP facilitates the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication. The program has developed a strategic plan in consultation with thousands of individuals in the research community, and its efforts provide a sound scientific basis for national and international decision making. CCSP is organized around five goals: (1) improving knowledge of climate history and variability, (2) improving the ability to quantify factors that affect climate, (3) reducing uncertainty in climate projections, (4) improving understanding of the sensitivity and adaptability of ecosystems and human systems to climate change, and (5) exploring options to manage risks.

The United States conducts technology research, development, demonstration, and deployment through the multi-agency CCTP. The program provides an interagency coordinating mechanism for climate technology research and development funding. This effort will lead to more cost-effective methods of reducing emissions and will facilitate more rapid development and commercialization of advanced technologies and best practices to help meet the long-term U.S. goal of reducing, and eventually reversing, GHG emissions. CCTP's strategic vision has six

complementary goals: (1) reducing emissions from energy use and infrastructure, (2) reducing emissions from energy supply, (3) capturing and sequestering CO_2, (4) reducing emissions of other GHGs, (5) measuring and monitoring emissions, and (6) bolstering the contributions of basic science.

Long-term, high-quality observations of the global environmental system are essential for understanding and evaluating Earth system processes and for providing sound information to decision makers. The United States contributes to the development and operation of global observing systems that combine data streams from both research and operational observing platforms to provide a comprehensive measure of climate system variability and climate change. The United States supports multiple oceanic, atmospheric, terrestrial, and space-based systems, working with international partners to enhance observations and improve data quality and availability.

In developing the CCSP roadmap, the United States recognized the need for enhanced observations and the importance of international cooperation in this area. To address key environmental data needs, the United States hosted the first Earth Observation Summit, in July 2003. At the third Earth Observation Summit, in Brussels in 2005, nearly 60 countries adopted a 10-year plan for implementing a Global Earth Observation System of Systems (GEOSS), which addresses multiple environmental data needs, including climate, weather, biodiversity, natural disasters, and water and energy resource management (GEO 2005).

EDUCATION, TRAINING, AND OUTREACH

Chapter 9 outlines how U.S. climate change education, training, and outreach efforts have continued to evolve. U.S. federal agencies—including the Agency for International Development; the Departments of Agriculture, Energy, the Interior, and Transportation; the Environmental Protection Agency; the National Aeronautics and Space Administration; the National Oceanic and Atmospheric Administration; and the National Science Foundation—work on a wide range of education, training, and outreach programs on the issues of U.S. climate change science, impacts, and mitigation. Each of these programs helps build the foundation for understanding and taking broad action to reduce the risks of climate change. The CCSP includes a communications working group that serves to provide policymakers and the public with information on the issue of global climate change and CCSP's efforts and accomplishments in this area.

Capacity building and training form an integral part of many federal agencies' international efforts on climate change. Efforts by industry, states, local governments, universities, schools, and NGOs are essential complements to federal programs that educate industry and the public regarding climate change. The combined efforts of the U.S. federal, state, and local governments and private entities are ensuring that the American public is better informed about climate change and more aware of the impact the Nation's choices may have on the sustainability of the planet.

2 National Circumstances

A number of factors influence the Nation's greenhouse gas (GHG) emissions, including government structure, climatic conditions, population growth, geography, economic growth, energy consumption, technology development, resource base, and land use. This chapter focuses on current circumstances and departures from historical trends since the third *U.S. Climate Action Report*[1] (CAR) was submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2002, and the impact of these changes on emissions and removals (U.S. DOS 2002).

GOVERNMENT STRUCTURE

The United States is the world's oldest federal republic. Governmental responsibilities affecting economic development, energy, natural resources, and many other issues are shared among local, state, and federal governments. Those interested in learning more about the U.S. government's structure should consult the 2002 CAR, Chapter 2.

POPULATION PROFILE

Population growth can have a significant impact on energy consumption, land-use patterns, housing density, and transportation. Recent data from the U.S. Census Bureau indicate that the U.S. population trends highlighted in the 2002 CAR remain unchanged. As of 2005, the United States was the third most populous country in the world, with an estimated 296.4 million people. From 2000 to 2005, the U.S. population grew by about 15 million, at an annual rate of about 1 percent. This growth was essentially unchanged from the annual rate during the 1990s and is relatively high compared to the growth rates of other industrialized countries (U.S. DOC/Census 2006a). Net immigration continues to have a significant and increasing effect on U.S. population growth. About 42 percent of the growth between 2000 and 2005 was due to immigration, and about 58 percent from natural increase (U.S. DOC/Census 2006b).

The warm "Sunbelt"—i.e., the U.S. South and Southwest—continues to show the greatest population growth. California, Texas, Florida, and Arizona experienced the largest absolute increase in population from 2000 to 2005 (U.S. DOC/Census 2006b). This preference for warmer climates has a mixed impact on energy use. In general, while homes in these areas use less energy for heating, they use more energy for cooling.

In addition to these regional trends, the U.S. population has shifted from rural to metropolitan areas. About 54 percent of the population lives in metropolitan areas of 1 million people or more (U.S. DOC/Census 2006c). Much of the growth in metropolitan areas has not been in city centers; instead, it has occurred in the surrounding suburbs and newly emerging "exurbs." Between 1997 and 2003, the number of houses in suburban metropolitan areas increased by 15.3 percent. The comparable figure for central cities was just 3.4

[1] See <http://unfccc.int/resource/docs/natc3.pdf>.

percent, and the number of homes outside of metropolitan areas declined by 2.2 percent (U.S. DOC/Census 1999, 2004). Coupled with the Nation's generally low population density, this decentralizing trend in metropolitan areas has implications for energy use. In the past, commuting patterns were largely between the central city and surrounding suburbs, whereas today there is a much greater amount of suburb-to-suburb commuting, increasing reliance on the automobile for transportation.

GEOGRAPHIC PROFILE

The United States is one of the largest countries in the world, with a total area of 9,192,000 square kilometers (3,548,112 square miles) stretching over seven time zones. The U.S. topography is diverse, featuring deserts, lakes, mountains, plains, and forests. More than 60 percent of the U.S. land area is privately owned. The U.S. government owns and manages the natural resources on about 28 percent of the land, most of which is managed as part of the national systems of parks, forests, wilderness areas, wildlife refuges, and other public lands. States and local governments own about 9 percent, and the remaining 2 percent is held in trust by the Bureau of Indian Affairs (Lubowski et al. 2006). While the private sector plays a major role in developing and managing U.S. natural resources, federal, state, and local governments regulate activities on privately owned lands and provide educational support to ensure the protection and sustainable management of the natural resources on these lands.

CLIMATE PROFILE

The climate of the United States varies greatly, ranging from tropical conditions in south Florida and Hawaii to arctic and alpine conditions in Alaska and the high elevations of the Rocky Mountains and Sierra Nevada. Temperatures for the continental United States show a strong gradient, from very high temperatures in south Florida, south Texas, and parts of southern California and Arizona, where the annual average temperature exceeds 21°C (70°F), to much cooler conditions in the northern parts of the country along the Canadian border.

Similarly, precipitation shows a strong gradient, measuring more than 127 centimeters (cm) (50 inches (in)) a year along the Gulf of Mexico, and decreasing to desert regions of the intermountain West. A similar but steeper gradient occurs in the Pacific Northwest, ranging from very high annual precipitation in the Cascades and Sierra Nevada, which can exceed 254 cm (100 in), to the rain shadows east of these mountain ranges, where annual precipitation can be less than 30 cm (12 in).

Seasonal variability in temperature also shows a very wide range with distance from the oceans. The difference between summer and winter temperatures is greater than 50°C (90°F) in areas like the northern Great Plains, whereas this difference is less than 8°C (14.4°F) in areas like south Florida. Seasonal variability in precipitation, however, shows a much different pattern. Areas in the eastern third of the country receive rainfall fairly consistently throughout the year. However, parts of the Great Basin (e.g., Arizona) experience two peaks in rainfall—one during the Pacific winter storms, and one in the mid to late summer during the peak of the North American monsoon. Along the West Coast, wet conditions prevail during the winter, and very dry conditions prevail during the summer.

The United States is subject to almost every kind of weather extreme, including countless severe thunderstorms during the warmer months of the year, and almost 1,500 tornadoes a year, most occurring during the spring and early summer. The hurricane season, which runs from June through November, produces an average of seven hurricanes, three of which make landfall. At any given time, approximately 20 percent of the country experiences drought conditions; however, during the largest droughts, almost 80 percent of the continental United States has been in moderate to severe drought. Blizzards, ice storms, and high wind events occur across the country during the winter, and cold waves often produce freezing temperatures in regions that rarely see these kinds of conditions.

Differing U.S. climate conditions are seen in the number of annual heating and cooling degree-days. From 2000 to 2004, the number of heating degree-days averaged 4,330, which was 4.3 percent below the 30-year normal average. Over the same period, the annual number of cooling degree-days averaged 1,283, which was 5.6 percent above normal (U.S. DOE/EIA 2006b). Figure 2-1 shows the U.S. geographic distribution of heating and cooling degree-days.

ECONOMIC PROFILE

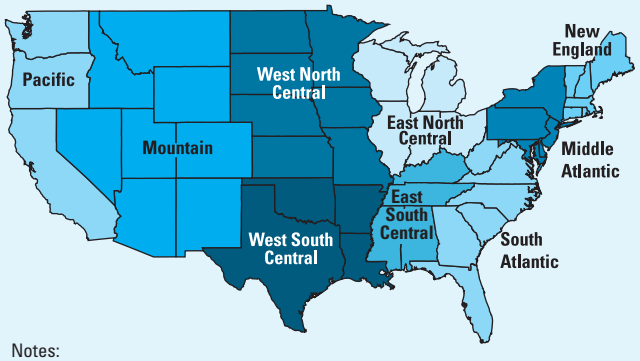
The U.S. economy is the largest in the world. In 2005, the U.S. economy continued a robust expansion, with strong output growth and steady improvement in the labor market. Looking to the future, the U.S. economy is poised for sustained growth for years to come.

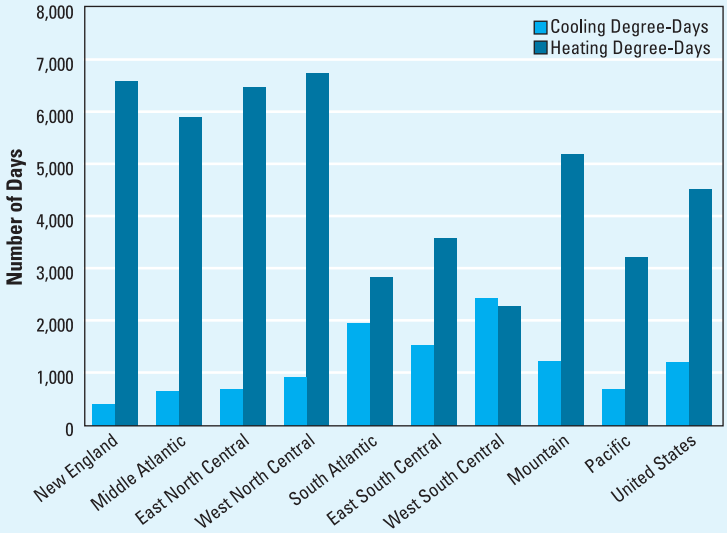
From 2000 to 2005, the U.S. economy grew by more than $1.3 trillion (in constant 2000 dollars), or 13.4 percent. In 2005, real gross domestic product (GDP) was just over $11.1 trillion (in constant 2000 dollars). Nonfarm payroll employment increased by 2.0 million during 2005, leading to an average unemployment rate of 5.1 percent. Since the business-cycle peak in the first quarter of 2001 (a period that included a recession and a recovery), labor productivity grew at an average 3.6-percent annual rate, notably higher than during any comparable period since 1948.

The performance of the U.S. economy in 2005 was a marked turnaround from the economic situation the Nation faced four years earlier. The bursting of the high-tech bubble of the late 1990s, slow growth among major U.S. trading partners, and the terrorist attacks of September 11, 2001, combined to dampen growth. Business investment slowed sharply in late 2000 and

FIGURE 2-1 **Cooling and Heating Degree-Days for the Continental United States** (30-Year Normals, 1971-2000)

Geographic cooling and heating patterns have a significant impact on the type and amount of energy consumed. Areas of the country with greater-than-average cooling degree-days typically use more energy for space cooling, while areas with greater-than-average heating degree-days typically use more energy for space heating.





Notes:
- Cooling and heating degree-days represent the number of degrees that the daily average temperature—the mean of the maximum and minimum temperatures for a 24-hour period—is below (heating) or above (cooling) 65°F (18.3°C). For example, a weather station recording a mean daily temperature of 40°F (11.3°C) would report 25 heating degree-days.
- Data for the Pacific region exclude Alaska and Hawaii.

Source: U.S. DOE/EIA 2006a.

remained soft for more than two years. The economy lost more than 900,000 jobs from December 2000 to September 2001, and nearly 900,000 more in the three months immediately following the September 11 attacks. This slowdown in economic growth contributed to an absolute drop in GHG emissions in 2001.

Substantial tax relief and monetary policy provided stimulus to aggregate demand that softened the recession and helped put the economy on the path to recovery. Pro-growth tax policies not only provided timely stimulus, but improved incentives for work and capital accumulation, fostering an environment favorable to long-term economic growth.

However, high energy prices, which weaken both the supply and the demand sides of the economy, restrained growth somewhat in 2004 and 2005. Strong global demand, especially in Asia, and supply disruptions combined to push the price of crude oil to about $50 per barrel. Several hurricanes also harmed the productive capacity of the economy, damaging Gulf Coast oil and gas platforms and refining installations. Despite these factors and a long series of interest rate hikes by the Federal Reserve, the economy grew a healthy 3.5 percent in 2005 (CEA 2006). Although world oil production capacity is expected to increase, so is world demand, and the United States is likely to face tight crude oil markets for a number of years, which could constrain GDP growth and GHG emissions.

Long-term trends in the relative contributions of industrial sectors to GDP have changed little since the 2002 CAR. As a share of GDP, the service sector continues to grow, while the manufacturing sector continues to decline (CEA 2006). This shift has been a factor in improving U.S. GHG emissions intensity.

ENERGY RESERVES, PRODUCTION, AND CONSUMPTION

The considerable size of the United States and its variable and often severe climatic conditions, large and growing population, dynamic economy and industries, and rich endowment of energy resources are all factors that contribute to making the Nation the world's largest producer and consumer of energy. Figure 2-2 provides an overview of energy flows through the U.S. economy in 2005. This section focuses on changes in U.S. energy supply and demand since the 2002 CAR, which covered energy through 2000.

Reserves and Production

The United States has vast reserves of energy, especially fossil fuels, which have been instrumental in the country's economic development. Uranium ore, renewable biomass, and hydropower are three other major sources of energy. Other renewable energy sources contribute a relatively small but growing portion of the U.S. energy portfolio.

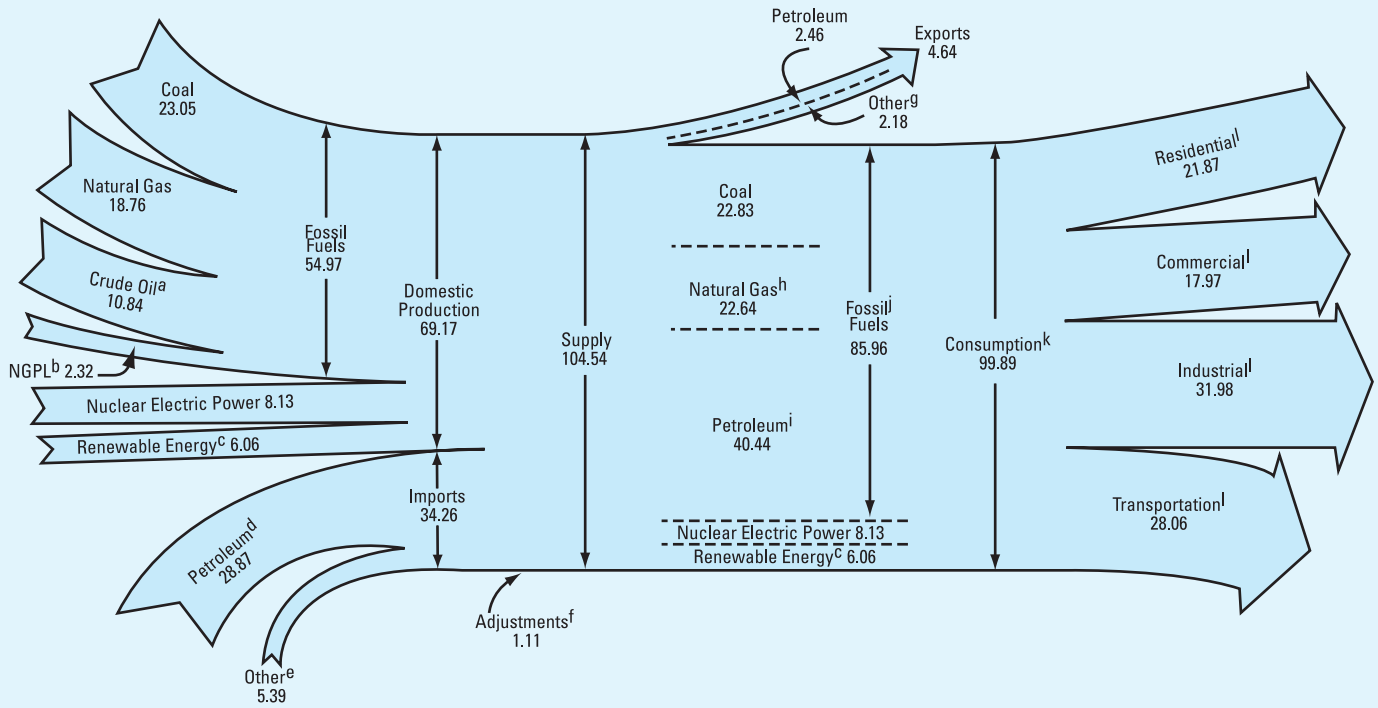
Fossil Fuels

Fossil fuels accounted for about four-fifths of U.S. domestic energy production in 2005, slightly less than in 2000.

Coal, which has the highest emissions of carbon dioxide (CO_2) per unit of energy, is particularly plentiful, and is the largest source of energy produced domestically. Coal remains the preferred fuel for power generation, supplying about half of the energy used to generate electricity in

FIGURE 2-2 **Energy Flow Through the U.S. Economy: 2005** (Quadrillion Btus)

The U.S. energy system is the world's largest, and it uses a diverse array of fuels from many different sources. The United States is largely self-sufficient in most fuels, except for petroleum. In 2005, net imports of crude oil and refined products accounted for about 65 percent of U.S. petroleum consumption on a Btu basis.



[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Conventional hydroelectric power, wood, waste, ethanol blended into motor gasoline, geothermal, solar, and wind.
[d] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[e] Natural gas, coal, coal coke, and electricity.
[f] Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.
[g] Coal, natural gas, coal coke, and electricity.
[h] Includes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids.
[j] Includes 0.04 quadrillion Btus of coal coke net imports.
[k] Includes, in quadrillion Btus: (1) 0.34 ethanol blended into motor gasoline, which is accounted for in both fossil fuels and renewable energy, but is counted only once in total consumption; and (2) 0.08 electricity net imports.
[l] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. Electrical system energy loss is the amount of energy lost during the generation, transmission, and distribution of electricity.

Notes:
- Data are preliminary.
- Values are derived from source data prior to rounding for publication.
- Totals may not equal sum of components due to independent rounding.

Source: U.S. DOE/EIA 2006b.

the United States. Moreover, from 2000 to 2005, coal's competitive position vis-à-vis oil and natural gas improved because of the rising cost of the latter fuels. Coal reserves are estimated at about 449 billion metric tons (495 billion tons), enough to last for about 440 years at current recovery rates. Annual coal production from 2000 to 2005 averaged about 1.0 billion metric tons (1.1 billion tons) (U.S. DOE/EIA 2006f).

The trends in oil reserves and production identified in the 2002 CAR have changed very little. Both peaked in 1970, when Alaskan North Slope fields came on line, and generally have declined since then. Proved domestic reserves of oil stand at about 3.4 trillion liters (21.9 billion barrels). At the 2005 production rate of about 912 billion liters (5.7 million barrels) per day, these reserves would be recovered in slightly less than 12 years (absent additions) (U.S. DOE/EIA 2006g).

U.S. refining capacity, while well off its 1981 peak, has increased since 1994, even as the number of refineries declines. Although the number of operable refineries fell from 158 to 148 from 2000 to 2005, refining capacity over the period actually rose from 26.3 billion to 27.2 billion liters (16.5 to 17.1 million barrels) per day (U.S.

DOE/EIA 2005e). However, this capacity is still well below the demand for petroleum products, which in 2005 averaged 32.8 billion liters (20.7 million barrels) per day.

In 2005, net imports of crude oil and refined products accounted for 60 percent of U.S. petroleum (volumetric) consumption, about 7 percentage points above the level for 2000.[2] In addition to strong global demand, the active hurricane season in 2005 temporarily affected Gulf Coast crude oil production and refining, which contributed to the rising cost of crude oil and petroleum products in 2005.

Natural gas is the fossil fuel with the lowest emissions of CO_2 per unit of energy. The 2002 CAR pointed to the introduction of market pricing and regulatory changes in the 1980s as factors that led to a recovery in natural gas production and demand. The addition of natural gas-fired electricity-generating capacity also has boosted demand. Estimated dry natural gas reserves of about 5.5 trillion cubic meters (192.5 trillion cubic feet) at the beginning of 2005 were 8.5 percent higher than reserves at the beginning of 2000. Natural gas production also increased since the 2002 CAR, but only modestly, rising 1 percent between 2000 and 2005 to 1.5 million cubic meters (53.2 million cubic feet) per day. As a result, the reserves-to-production ratio increased from 9.2 to 10.6 years (U.S. DOE/EIA 2006g).

Nuclear Energy

The United States has about 120 million kilograms (kg) (265 million pounds (lb)) of uranium oxide reserves recoverable at $66 per kg ($30 per lb) (U.S. DOE/EIA 2004b). Although U.S. uranium production has been trending downward for many years, production saw a turnaround in 2004, as U.S. uranium drilling, mining, production, and employment activities increased for the first time since 1998. Total U.S. uranium concentrate production in 2005 was about 1.2 million kg (2.7 million lb). Although well below its 1980 peak, it was 35 percent above the 2003 level (U.S. DOE/EIA 2005a).

Production from nuclear energy facilities in 2005 contributed 20 percent of total electricity generation[3] and 12 percent of total domestic energy production.

Renewable Energy

Renewable energy production in 2005 was 6.1 quadrillion Btus, accounting for 8.8 percent of total U.S. energy production. Of this amount, biomass accounted for 46 percent; hydropower, 45 percent; geothermal, 5.8 percent; wind, 2.5 percent; and solar, 1.1 percent. Owing largely to higher than normal hydropower output, renewable energy production reached its highest point in 1996 at 7.1 quadrillion Btus, or just below 10 percent of total U.S. energy production,

After peaking in 1997, hydropower production declined for four consecutive years, and has been at normal or below-normal levels since 2000. Geothermal output in 2005 reached its highest level since 1993. Wind expanded rapidly in recent years, but its share of the total was not enough to significantly affect the overall renewable industry trend (U.S. DOE/EIA 2006e).

Electricity

The United States relies on electricity to meet a significant portion of its energy demands, especially for lighting, electric motors, heating, and air-conditioning. The electricity generation sector, the largest U.S. economic sector, is composed of traditional electric utilities as well as other entities, such as power markets and non-utility power producers.

Coal-fired capacity in 2005 maintained the largest share of U.S. electric generating capacity, at 32 percent. Natural gas capacity accounted for 23 percent of the total generating capacity; dual-fired (natural gas and petroleum), 18 percent; nuclear, 10 percent; hydroelectric, 8 percent; and other renewables (wood products, solar, wind, etc.), 2 percent.

While coal-fired capacity remains the largest, its share of total capacity fell relative to other fuels, particularly natural gas. In 2004, 72 percent of the new unit capacity was natural gas-fired, and at 15.3 gigawatts was well ahead of natural gas plant retirements. Also notable was the growth in renewable capacity, which added about 9 megawatts for every megawatt retired. Additionally, re-powering of large coal-fired plants into more efficient natural gas combined-cycle plants, as well as the retirement of older coal-fired units, has slightly reduced coal-fired capacity. However, new orders for natural gas-fired units could slow because of high fuel costs.

In 2005, net generation of electricity was 4.06 trillion kilowatt-hours, 6.7 percent above the 2000 level. Regulated electric utilities' share of total generation continues to decline as independent power producers' share continues to increase (U.S. DOE/EIA 2005c). Although coal-fired capacity represents roughly one-third of total generating capacity, it accounts for about half of the electricity generated. This is because coal-fired plants are for the most part run constantly to meet base-load capacity, rather than sporadically to meet peak-load demand.

Consumption

Since 2000, the overall trend in U.S. energy demand has been driven largely by economic activity. From 2000 to 2001, total U.S. energy consumption fell 2.5 percent, primarily in response to weakness in the U.S. economy and the effects of increased oil prices. As the economy began to recover in 2002, energy consumption also picked up. By 2004, U.S. energy consumption topped 100 quadrillion Btus, before dipping slightly in 2005, owing in part to hurricane-related damage along the Gulf Coast and Florida. Figure 2-3 presents U.S. energy use by sector.

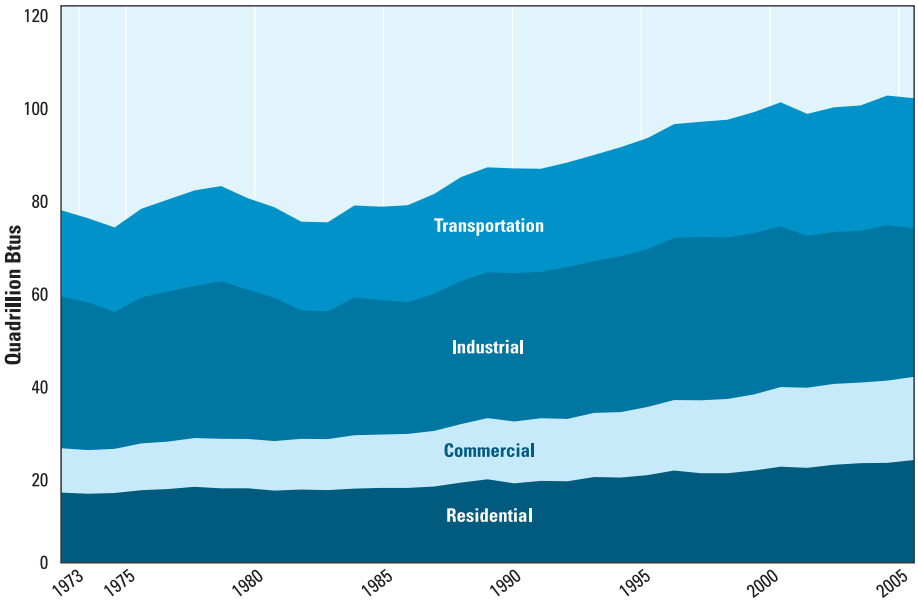
While absolute U.S. energy use has risen since 2000, the amount of energy

[2] On a Btu basis, net petroleum imports accounted for 65 percent of U.S. petroleum consumption in 2005, about 7 percentage points higher than in 2000.

[3] For the electric power sector; excludes electricity production in the commercial and industrial sectors.

FIGURE 2-3 **U.S. Energy Consumption by Sector: 1973-2005**

Between 2000 and 2005, energy consumption in the residential, commercial, and transportation sectors rose by 6.6, 4.4, and 5.0 percent, respectively, while energy demand in the industrial sector fell by 7.6 percent. Since 1973, the industrial sector has accounted for a gradually shrinking portion of total energy consumed in the United States, falling from 43 percent to less than one-third in 2005.



Source: U.S. DOE/EIA 2006e.

used per dollar of economic output—the energy intensity of the U.S. economy—has declined on average by 1.9 percent a year. From 10,100 Btus per dollar in 2000, U.S. energy intensity dropped by 11 percent to 9,000 Btus (per 2000 dollar) in 2005. These data reflect a continuing trend driven by advances in energy technology and efficiency, and by the growing importance of service industries and the declining contribution of energy-intensive industries to the GDP. Between 1992 and 2004, the energy-intensive industries' share of total industrial production fell by 1.3 percent a year on average (U.S. DOE/EIA 2006a).

Petroleum remains the largest single source of U.S. energy consumption; in 2005 it accounted for 41 percent of total U.S. energy demand. Other major energy sources consumed include natural gas, at 24 percent; coal, at 23 percent; nuclear, at 8 percent; and renewables, at 6 percent (U.S. DOE/EIA 2006e).

Emissions of CO_2 from energy reflect the changing economic conditions and adoption of more energy-efficient technologies over the period since the 2002 CAR. While CO_2 emissions from fossil fuel combustion tracked economic growth, the intensity of CO_2 emissions from fossil fuel combustion—measured as the ratio of metric tons of CO_2 emitted per $1,000 of real gross domestic product—declined steadily over the period, from 0.59 in 2000 to 0.54 in 2004, the latest year for which data are available (U.S. DOE/EIA 2006d).

Residential Sector

The residential sector is made up of living quarters for private households. Common uses of energy associated with this sector include space heating—the largest single source of residential energy consumption—water heating, air conditioning, lighting, refrigeration, cooking, and running a variety of other appliances.[4] In 2005, energy consumption in this sector, including electricity losses, totaled 21.9 quadrillion Btus, or 22 percent of U.S. consumption. About one-fifth of GHG emissions from burning fossil fuels is attributable to residential buildings.

Between 2000 and 2005, total energy consumption in the residential sector rose 6.6 percent. As more people move to warmer climates, and as plug load from consumer electronics continues to grow, electricity is expected to comprise a growing share of energy consumption in this sector, a trend that is reflected in the consumption data. From 2000 to 2005, electricity consumption, including system losses, increased every year, regardless of weather or economic conditions; in 2005 it accounted for 68 percent of total residential energy consumption[5] (U.S. DOE/EIA 2006e).

Compared to electricity, demand for petroleum (primarily fuel oil) and natural gas is much more variable and fluctuates seasonally, regionally, and annually based on winter temperatures. Consumption of natural gas during 2000–2005 peaked in 2003, largely because of high demand for natural gas brought on by a relatively cold winter heating season throughout much of the country. Demand also was affected by changes in relative prices between natural gas and its substitutes.

Commercial Sector

Service-providing facilities and equipment of businesses, governments, and private and public organizations, institutional living quarters, and sewage treatment plants are the main components that make up the commercial sector. The most common uses of energy in this sector include space ventilation and air conditioning, water heating, lighting, refrigeration, cooking, and running a wide variety of office and other equipment. A relatively small portion is used for transportation. In

[4] For data on the energy-consuming characteristics of U.S. households, see Figure 2-8 of the 2002 CAR.

[5] Total electricity, including retail sales and energy losses.

2005, total energy in the commercial sector was 4.4 percent higher than in 2000. At nearly 18 quadrillion Btus, it represented 18 percent of total U.S. energy demand and approximately 18 percent of GHG emissions from fossil fuel consumption.

Electricity, including system losses,[6] supplies a little over three-quarters of energy used by the sector, and natural gas, about 18 percent. Demand for these fuels responded largely to a combination of prices and weather, although normally the impact of weather is less marked than in the residential sector. Demand for electricity increased every year except 2003. In 2005, electricity retail sales were about 9.1 percent higher than in 2000, while natural gas demand, which is more variable, fluctuated over the period (U.S. DOE/EIA 2006e).

Industrial Sector

The industrial sector consists of all facilities and equipment used for producing, processing, or assembling goods, including manufacturing, mining, agriculture, and construction. Since 1973, the industrial sector has accounted for a gradually shrinking portion of total energy consumed in the United States, falling from 43 percent to about one-third in 2005. Fossil fuel-related CO_2 emissions from the industrial sector also have fallen by about 33 percent since 1990, and account for about 28 percent of total U.S. CO_2 emissions.

Overall energy use in the industrial sector is largely for process heating and cooling and powering machinery, with lesser amounts used for facility heating, air conditioning, and lighting. Fossil fuels are also used as raw material inputs to manufactured products. Approximately four-fifths of the total energy used in the industrial sector is for manufacturing, with chemicals and allied products, petroleum and coal products, paper and nonmetallic minerals, and primary metals accounting for most of this share.

Electricity use, including system losses, represents a little more than one-third of all energy consumed in the industrial sector, while petroleum and natural gas account for 30 percent and 25 percent, respectively.

Since the 2002 CAR, economic conditions and high energy costs affected industrial and manufacturing outputs, which were declining or flat until 2004, when both increased significantly. Nevertheless, compared to 2000, energy demand in this sector was 7.6 percent lower in 2005. At 7.9 quadrillion Btus in 2005, natural gas demand was at its lowest level in this sector since 1988. Coal and electricity consumption also has not returned to 2000 levels, but by 2005 petroleum consumption was 5.7 percent higher than in 2000 (U.S. DOE/EIA 2006e).

Transportation Sector

Energy consumption in the transportation sector includes all energy used to move people and goods: automobiles, trucks, buses, and motorcycles; trains, subways, and other rail vehicles; aircraft; and ships, barges, and other waterborne vehicles.[7] Total energy demand in this sector accounts for nearly 28 percent of total U.S. energy demand and approximately one-third of GHG emissions from fossil fuels.

In 2005, petroleum supplied 98 percent of the energy used in the transportation sector. Transportation is responsible for about two-thirds of all the petroleum used, and personal transportation accounts for 60 percent of this consumption.

Slower economic growth and the terrorist attacks of September 11, 2001, were the major factors affecting energy demand in this sector since the 2002 CAR. Overall, transportation-related energy demand dropped 1.6 percent between 2000 and 2001, which was confined largely to aviation jet fuel (especially in the two years after the September 11 attacks) and residual fuel oil (e.g., bunker fuels). However, demand rose in each subsequent year, reaching a historic high of 28 quadrillion Btus in 2005, which was 5 percent above the 2000 level (U.S. DOE/EIA 2006e). The basic factors affecting energy demand in this sector that were identified in the 2002 CAR—increasingly decentralized land-use patterns, population growth, and economic expansion—continue to drive much of the increase in the sector's energy consumption.

Concerns about methyl tertiary butyl ether (MTBE) contamination of groundwater from leaking storage tanks have led several states to institute bans on MTBE. As a result, ethanol use has grown significantly as a transportation fuel over the past few years, jumping from 139 trillion Btus in 2000 to 340 trillion Btus in 2005 (U.S. DOE/EIA 2006c). As CO_2 emissions from ethanol consumption are not net additions to the atmosphere (as long as no new land is put into production), this trend has tended to mitigate the growth of transportation-related emissions.

Federal Government

The U.S. government remains the Nation's largest single user of energy. Under the Federal Energy Management Program, federal agencies have invested in energy efficiency over the past two decades. The U.S. government's total primary energy consumption—including energy consumed to produce, process, and transport energy—was 1.65 quadrillion Btus during fiscal year 2004, about 1.7 percent of total U.S. energy consumption.[8] Combined, federal agencies reported a 22 percent decrease in total primary energy consumption, compared to consumption during fiscal year 1990 (U.S. DOE 2006a).

Executive Order 13123 establishes a number of goals that go beyond what is required under the National Energy Conservation Act. These include goals related to improved energy efficiency and GHG reduction in federal buildings, renewable

[6] Electrical system energy loss is the amount of energy lost during generation, transmission, and distribution of electricity.
[7] Transportation does not include such vehicles as construction cranes, bulldozers, farming vehicles, warehouse tractors, and forklifts, whose primary purpose is not transportation.
[8] Just over 1.1 quadrillion Btus for site-delivered energy consumption.

energy, reduction of petroleum use, reduction of primary energy use, and water conservation.

The GHG reduction goal for federal government facilities—which includes standard buildings and industrial, laboratory, and other energy-intensive facilities—was set at 30 percent below 1990 levels by 2010. Recent data show emissions from these facilities have decreased by 19.4 percent since fiscal year 1990, from 54.7 teragrams of CO_2 equivalent (Tg CO_2 Eq.) in fiscal year 1990 to 44.1 Tg CO_2 Eq. in fiscal year 2004 (U.S. DOE 2006b).

TRANSPORTATION

The U.S. transportation system has evolved to meet the needs of a highly mobile, dispersed population and a large, dynamic economy. Over the years, the United States has developed an extensive multimodal system that includes waterborne, highway, mass transit, air, rail, and pipeline transport capable of moving large volumes of people and goods long distances. For-hire transport services account for 2.8 percent of GDP (U.S. DOC/BEA 2006b).

Economic circumstances, increased oil prices, and the terrorist attacks of September 11, 2001, interrupted some of the long-term trends noted in the 2002 CAR. Automobiles and light trucks still dominate the passenger transportation system, and the highway share of passenger kilometers traveled in 2003 was about 90 percent of the total, relatively unchanged from the 2002 CAR. Air travel accounted for a little less than 10 percent, and mass transit and rail travel combined accounted for only about 1 percent of passenger kilometers traveled. The following sections focus on changes in transportation since the 2002 CAR.

Highway Vehicles

The trends in highway vehicles described in the 2002 CAR have not changed appreciably. Vehicle ownership continues to increase. Between 1997 and 2004, the number of passenger vehicles rose nearly 15 percent to 243.0 million, about 1.2 vehicles for every licensed driver. This high degree of vehicle ownership, which reflects a strong desire for personal mobility, affects and is affected by population distribution, land-use patterns, location of work and shopping, energy use, and GHG emissions. It also contributes to decreased use of carpooling and public transport.

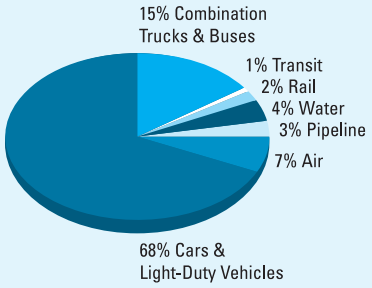
Passenger cars account for more than half of highway vehicles and over one-third of all the energy consumed in the transportation sector (Figure 2-4). However, between 1997 and 2004, the number of registered light trucks, sport utility vehicles, and vans increased by a combined 31 percent. In 2004, they made up nearly 38 percent of the highway vehicle fleet and used almost 28 percent of all the energy in the transportation sector. Though these types of vehicles are generally less energy efficient, consumers often choose them on the basis of other concerns, such as safety, affordability, capacity, and aesthetics. More recent data suggest that sales of light trucks as a percent of total vehicle sales have declined.

The number of miles driven is another major factor affecting energy use in the highway sector. From 1997 to 2003, the average number of kilometers driven per vehicle each year increased by 1 percent, and the total number of vehicle kilometers traveled increased by 16 percent.

Despite the large increase in the total number of vehicle kilometers traveled, associated increases in energy consumption have been more moderate, due to enhanced fuel efficiencies driven in part by the corporate average fuel economy (CAFE) standards for cars (11.7 kilometers per liter (kpl), or 27.5 miles per gallon (mpg)) and light trucks (8.8 kpl, or 20.7 mpg). In 2004, new passenger cars entering the U.S. fleet averaged 12.4 kpl (29.3 mpg), and new trucks averaged 9.1 kpl (21.5 mpg), compared to 12.2 and 8.8 kpl (28.7 and 20.7 mpg), respectively, in 1997. However, the growing portion of less fuel-efficient light trucks in the vehicle fleet has offset these efficiency gains somewhat. In 2006, fuel economy standards were raised for model years 2008–11, using an innovative vehicle, size-based approach, reaching 10.2 kpl (24.0 mpg) for model year 2011. This reform is expected to save 40.5 billion liters (10.7 billion gallons) of fuel.

FIGURE 2-4 Share of Transportation Energy Consumption by Mode: 2003

In 2003, cars and light-duty vehicles accounted for just over two-thirds of the energy consumed in the transportation sector.



Source: U.S. DOT 2006.

Air Carriers

The terrorist attacks of September 11, 2001, the slowdown in economic activity in 2001, and industry restructuring had a significant impact on the airline industry since the 2002 CAR. In 2001, U.S. domestic passenger kilometers dropped sharply by 5.7 percent from the previous year, and dipped another 0.9 percent in 2002. However, a recovering economy helped push domestic airline passenger distance traveled to 896 billion kilometers (558 billion miles) in 2003, 8.1 percent above the 2000 level.

Increased competitive pressures and the higher cost of aviation fuel were among the factors contributing to a 19 percent improvement in the energy efficiency of domestic industry operations between 1997 and 2004, based on energy used per passenger kilometer.

Freight

From 1997 to 2003 (the latest year for which data for all modes are available), U.S. freight transportation grew by 5.3 percent to 6.36 trillion metric ton kilometers (4.36

trillion ton miles). The predominant mode of freight transportation was rail (37 percent), followed by trucks (29 percent), pipelines (20 percent), waterways (14 percent), and air (less than 1 percent).

Revenue per metric ton kilometer for railroads grew by nearly 15 percent between 1997 and 2003. While the number of railroad cars in use also rose, it did so at a much slower pace (less than 1 percent). With comparatively fewer cars being called on to carry more freight greater distances, the energy intensity of Class 1 railroad freight services, measured as Btus per metric ton kilometer of freight, improved by 7 percent.

Freight trucks are the second largest consumers of energy in the transport sector, behind a category of vehicles comprising passenger cars and light-duty vehicles. Between 1997 and 2003, their share of energy use rose from 11 to 14 percent. The total amount of energy consumed by freight trucks increased by about one-third over the period. The number of registered combination trucks increased by about 12 percent, and the number of metric ton kilometers of freight increased by 13 percent.

Metric ton kilometers shipped by air grew steadily from 1997 to 2000, before dropping sharply (16 percent) in 2001. While air freight recovered over the next two years, its 2003 level was still below its 2000 peak. The metric ton kilometers shipped by domestic water transport declined from 1997 to 2003, a continuation of a long-term trend. Water transport metric ton kilometers fell by 14 percent over the period, led largely by declines in coastwise and lakewise shipping (U.S. DOT 2006a).

INDUSTRY

The U.S. industrial sector boasts a wide array of light and heavy industries in manufacturing and nonmanufacturing subsectors, the latter of which include mining, agriculture, and construction. Together, the value added of manufacturing and nonmanufacturing activities accounts for about 20 percent of total GDP, with utilities adding another 2 percent.

Relative to the economy as a whole, the industrial sector overall has shown slower output growth in recent decades, and imports have met a growing share of demand for industrial goods. From 1990 to 2005, the value added by manufacturing fell from 16.3 percent to 12.1 percent of total GDP, with declines in both durable and nondurable goods.[9] The shares attributed to agriculture and utilities also fell.

In contrast, mining rose from 1.5 percent to 1.9 percent of GDP, owing to a recovery in oil and gas extraction that began around 2000. After falling in the early 1990s, construction's share also rose, boosted by rapid growth in the housing sector (U.S. DOC/BEA 2006b).

The energy intensity of the industrial sector has improved appreciably. Delivered energy consumption is roughly the same today as it was in 1980, despite a more than doubling of GDP and a 50 percent increase in the value of shipments. Within the industrial sector, manufacturing activities are more energy-intensive than nonmanufacturing activities, using about 50 percent more energy per dollar of output. Since the mid-1980s, energy intensity declined more rapidly for nonmanufacturing than for manufacturing industries, primarily because most of the historical reduction in energy intensity in manufacturing had already occurred in response to the high energy prices of the late 1970s and early 1980s. Much of the decline in energy intensity in nonmanufacturing activities resulted from a compositional shift, with the relatively low-intensity construction industry growing more rapidly than the relatively high-intensity mining sector, particularly in the late 1990s and early 2000s (U.S. DOE/EIA 2006a).

WASTE

The 2002 CAR reported waste data through 1999. This section updates these data to 2004, the most recent reporting year available. In 2004, the United States generated approximately 247 million metric tons (272 million tons) of municipal solid waste (MSW), about 17 million metric tons (nearly 19 million tons) more than in 1999. Paper and paperboard products made up the largest component of MSW generated by weight (35 percent), and yard trimmings comprised the second largest material component (more than 13 percent). Glass, metals, plastics, wood, and food each constituted between 5 and 12 percent of the total MSW generated. Rubber, leather, and textiles combined made up about 7 percent of the MSW, while other miscellaneous wastes comprised approximately 3 percent of the MSW generated in 2004. These shares have not change appreciably since the 2002 CAR.

Recycling has resulted in a change in waste management from a GHG perspective (U.S. EPA 2006b). From 1990 to 2004, the recycling rate increased from just over 16 percent to about 32 percent. Of the remaining MSW generated, about 14 percent is combusted and 55 percent is disposed of in landfills. The number of operating MSW landfills in the United States has decreased substantially over the past 20 years, from about 8,000 in 1988 to about 1,654 in 2004, while the average landfill size has increased.

Landfills are the largest U.S. source of anthropogenic methane emissions, accounting for 25 percent of the total. Present data suggest a marked increase in the amount of methane recovered for either gas-to-energy or flaring purposes in recent years (U.S. EPA/OAP 2006c).

[9] Durable goods include wood products; nonmetallic mineral products; primary metals; fabricated metal products; machinery; computer and electronic products; electrical equipment, appliances, and components; motor vehicles, bodies and trailers, and parts; other transportation equipment; furniture and related products; and miscellaneous manufacturing. Nondurable goods include food and beverage and tobacco products; textile mills and textile product mills; apparel and leather and allied products; paper products; printing and related support activities; petroleum and coal products; chemical products; and plastics and rubber products.

BUILDING STOCK AND URBAN STRUCTURE

Buildings are large users of energy. Their number, size, and distribution and the appliances and heating and cooling systems that go into them influence energy consumption and GHG emissions. About 37 percent of total U.S. energy consumption and about 70 percent of total electricity consumption are in buildings.

Residential Buildings

The economic slowdown had little effect on the housing market, which has remained relatively strong since the 2002 CAR. Between 1997 and 2003, the number of residences in the United States grew by 8.3 percent to approximately 121 million households, 62 percent of which were single, detached dwellings.

Most of the recent growth in housing has occurred in the U.S. South and West. Combined, between 1997 and 2003 these two regions added nearly three times as many homes to the U.S. building stock as the Northeast and Midwest. The sustained growth in new housing in the Sunbelt, where almost all new homes have air conditioning, and the increasing market penetration of consumer electronics will continue to fuel the demand for residential electricity.

The desire for larger lots and more affordable housing has helped drive the decentralizing trend observed in metropolitan areas, and has created greater demand for more and larger homes. Between 1997 and 2003, the share of housing units of four or fewer rooms fell, while the shares of units with five to seven rooms and with eight to ten or more rooms rose (U.S. DOC/Census 1999, 2004).

While new homes are larger and more plentiful, their energy efficiency has increased greatly. In 2004, 8 percent of all new single-family homes were certified as ENERGY STAR compliant, implying at least a 30 percent energy savings for heating and cooling relative to comparable homes built to current code (U.S. DOE/EIA 2006a). New homes are on average about 13 percent larger than the stock of existing homes, and thus have greater requirements for heating, cooling, and lighting. Nevertheless, under current building codes and appliance standards for heat pumps, air conditioners, furnaces, refrigerators, and water heaters, the energy requirement per square foot of a new home is typically lower than of an existing home (U.S. DOE/EIA 2005b).

Commercial Buildings

Between 2000 and 2003, commercial floor space rose an estimated 1.8 percent a year. By 2003 there were nearly 4.9 million commercial buildings and more than 6.7 billion square meters (71.7 billion square feet) of floor space. Much of this growth has been related to the rapidly expanding information, financial, and health services sectors.

More than half of commercial buildings are 465 square meters (5,000 square feet) or smaller, and nearly three-fourths are 929 square meters (10,000 square feet) or smaller. Just 2 percent of buildings are larger than 9,290 square meters (100,000 square feet), but these large buildings account for more than one-third of commercial floor space (U.S.DOE/EIA 2003).

Electricity and natural gas are the two largest sources of energy used in commercial buildings. Over 85 percent of commercial buildings are heated, and more than 75 percent are cooled. The use of computers and other office electronic equipment continues to grow and will have an impact on the demand for electricity (U.S. DOE/EIA 2006a).

AGRICULTURE AND GRAZING

Agriculture in the United States is highly productive. U.S. croplands produce a wide variety of food and fiber crops, feed grains, oil seeds, fruits and vegetables, and other agricultural commodities for both domestic and international markets. In 2002, U.S. cropland was 137.6 million hectares (ha) (399.9 million acres (ac)) , about 2.6 percent lower than in 1997 (Lubowski et al. 2006).

Conservation is an important objective of U.S. farm policy. The U.S. Department of Agriculture administers a set of conservation programs that have been highly successful at removing environmentally sensitive lands from commodity production and encouraging farmers to adopt conservation practices on working agricultural lands. The largest of these programs, the Conservation Reserve Program (CRP), seeks to reduce soil erosion, improve water quality, and enhance wildlife habitat by retiring environmentally sensitive lands from crop production. About 16 million ha (39.5 million ac) of land is enrolled in CRP.

Improved tillage practices also have helped reduce soil erosion and conserve and build soil carbon levels. From 1998 to 2004, the amount of cropland managed with no-till systems increased by 31 percent to 25.4 ha (62.7 ac), in part because of the widespread adoption of herbicide-tolerant crops developed using biotechnology. Land managed using all conservation tillage systems has fluctuated between about 40 and 46 million ha (98.8 and 113.6 million ac) (CTIC 2004).

Sources of GHG emissions from U.S. croplands include nitrous oxide from nitrogen fertilizer use and residue burning and methane from rice cultivation and residue burning. Nitrous oxide related to fertilizer use is by far the largest source, representing more than 97 percent of emissions from croplands (U.S. EPA/OAP 2006c).

Grasslands account for slightly more than one-third of the major U.S. land uses. Pasture and range ecosystems can include a variety of different flora and fauna communities, and are generally managed by varying grazing pressure, by using fire to shift species abundance, and by occasionally disturbing the soil surface to improve water infiltration. In 2002, grasslands totaled about 316 million ha (780.5 million ac), about the same as in 1997. Since 1949, grassland acreage has declined by about 8 percent, reflecting improved productivity

of grazing lands, land-use changes, and a decline in the number of domestic animals raised on grazing lands (Lubowski et al. 2006).

FORESTS

U.S. forests are predominately natural stands of native species, and vary from the complex hardwood forests in the East to the highly productive conifer forests of the Pacific Coast. Planted forest land is most common in the East, and planted stands of native pines are common in the South. In 1630, forest land comprised an estimated 46 percent of the total U.S land area, whereas in 2002, forests covered about one-third of the total area. Historically, most of the forest land loss was due to agricultural conversions, but today most losses are due to such intensive uses as urban development.

Of the 303 million ha (748.4 million ac) of U.S. forest land, nearly 204 million ha (503.9 million ac) are timberland, most of which is privately owned in the conterminous United States. However, a significant area of forest land is reserved forests, which in 2002 accounted for about one-third of forest land, about 99 million ha (244.5 million ac) (Lubowski et al. 2006).

Since the 1950s, timber growth for both softwoods and hardwoods in the United States has consistently exceeded harvests. In 2001, net growth exceeded removals by 33 percent (i.e., U.S. forest inventory accrued more volume than it lost by mortality and harvest by nearly one-third). Recent declines in harvesting on public lands in the West have significantly deviated from historic growth and removal patterns, and have placed more pressure on eastern forests that are predominantly in private ownership (Smith et al. 2004).

Existing U.S. forests are an important net sink for atmospheric carbon. Improved forest management practices, the regeneration of previously cleared forest areas, as well as timber harvesting and use have resulted in net sequestration of CO_2 every year since 1990 (U.S. EPA/OAP 2006c).

3 Greenhouse Gas Inventory

An emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases is essential for addressing climate change. The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c) adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contributions of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available … national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the *Montreal Protocol*, using comparable methodologies…."[2] The United States views the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OPA 2006b) as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990 through 2004. To ensure that the U.S. emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the Intergovernmental Panel on Climate Change (IPCC) *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the IPCC *Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003). The structure of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* is consistent with the UNFCCC guidelines for inventory reporting.[3] For most source categories, the IPCC methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). As stratospheric ozone-depleting substances (ODS), CFCs, HCFCs, and halons are covered

[1] The term *anthropogenic*, in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes affected by human activities (IPCC/UNEP/OECD/IEA 1997).

[2] Article 4(1)(a) of the UNFCCC (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. See <http://unfccc.int/essential_background/convention/background/items/1349.php>.

[3] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

under the *Montreal Protocol on Substances That Deplete the Ozone Layer*. The UNFCCC defers to this earlier international treaty. Consequently, Parties to the UNFCCC are not required to include these gases in their national greenhouse gas emission inventories.[4] Some other fluorine-containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone, but are potent greenhouse gases. These latter substances are addressed by the UNFCCC and accounted for in national greenhouse gas emission inventories.

There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial and/or solar radiation absorption by influencing the formation or destruction of greenhouse gases, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and nonmethane volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO_2) or elemental carbon emissions, can also affect the absorptive characteristics of the atmosphere.

Although the direct greenhouse gases CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2004, concentrations of these greenhouse gases have increased globally by 35, 143, and 18 percent, respectively (IPCC 2001; Hofmann 2004).

Beginning in the 1950s, the use of CFCs and other stratospheric ODSs increased by nearly 10 percent per year until the mid-1980s, when international concern about ozone depletion led to the entry into force of the *Montreal Protocol*. Since then, the production of ODSs is being phased out.

[4] Emission estimates of CFCs, HCFCs, halons, and other ODS are included in the annexes of the Inventory report for informational purposes.

[5] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

Emissions Reporting Nomenclature

The global warming potential (GWP)-weighted emissions of all direct greenhouse gases throughout this chapter are presented in terms of equivalent emissions of carbon dioxide (CO_2), using units of teragrams of CO_2 equivalent (Tg CO_2 Eq.). The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) (2.2 pounds (lb)) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001a). The relationship between gigagrams (Gg) of a gas and Tg CO_2 Eq. can be expressed as follows:

$$\text{Tg } CO_2 \text{ Eq.} = (\text{Gg of gas}) \times (\text{GWP}) \times \left(\frac{\text{Tg}}{1{,}000 \text{ Gg}}\right)$$

The UNFCCC reporting guidelines for national inventories were updated in 2002,[5] but continue to require the use of GWPs from the IPCC Second Assessment Report (IPCC 1996b). The GWP values used in this report are listed below in Table 3-1, and are explained in more detail in Chapter 1 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c).

TABLE 3-1 Global Warming Potentials (100 Year Time Horizon) Used in This Report

The concept of a global warming potential (GWP) has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. Carbon dioxide was chosen as the reference gas to be consistent with IPCC guidelines.

Gas	GWP
CO_2	1
CH_4*	21
N_2O	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

* The methane GWP includes the direct and indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.
Source: IPCC 1996b.

In recent years, use of ODS substitutes, such as HFCs and PFCs, has grown as they begin to be phased in as replacements for CFCs and HCFCs. Accordingly, atmospheric concentrations of these substitutes have been growing (IPCC 2001a).

RECENT TRENDS IN U.S. GREENHOUSE GAS EMISSIONS AND SINKS

In 2004, total U.S. greenhouse gas emissions were 7,074.4 Tg CO_2 Eq. Overall, total U.S. emissions rose by 15.8 percent from 1990 through 2004, while the U.S. gross domestic product increased by 51 percent over the same period (U.S. DOC/BEA 2006a). Emissions rose from 2003 through 2004, increasing by 1.7 percent (115.3 Tg CO_2 Eq.). The following factors were primary contributors to this increase: (1) robust economic growth in 2004, leading to increased demand for electricity and fossil fuels; (2) expanding industrial production in energy-intensive industries, also increasing demand for electricity and fossil fuels; and (3) increased travel, leading to higher rates of consumption of petroleum fuels.

Figures 3-1 through 3-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Table 3-2 provides a detailed summary of U.S. greenhouse gas emissions and sinks from 1990 through 2004.

Figure 3-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2004. The primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 85 percent of total greenhouse gas emissions. The largest source of CO_2, and of overall greenhouse gas emissions, was fossil fuel combustion. CH_4 emissions, which have steadily declined since 1990, resulted primarily from decomposition of wastes in landfills, natural gas systems, and enteric fermentation associated with domestic livestock. Agricultural soil management and mobile source fossil fuel combustion were the major sources of N_2O emissions. The emissions of ODS substitutes and

FIGURE 3-1 Growth in U.S. Greenhouse Gas Emissions by Gas

In 2004, total U.S. greenhouse gas emissions rose to 7,074.4 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.), which was 15.8 percent above 1990 emissions. The U.S. gross domestic product increased by 51 percent over the same period.

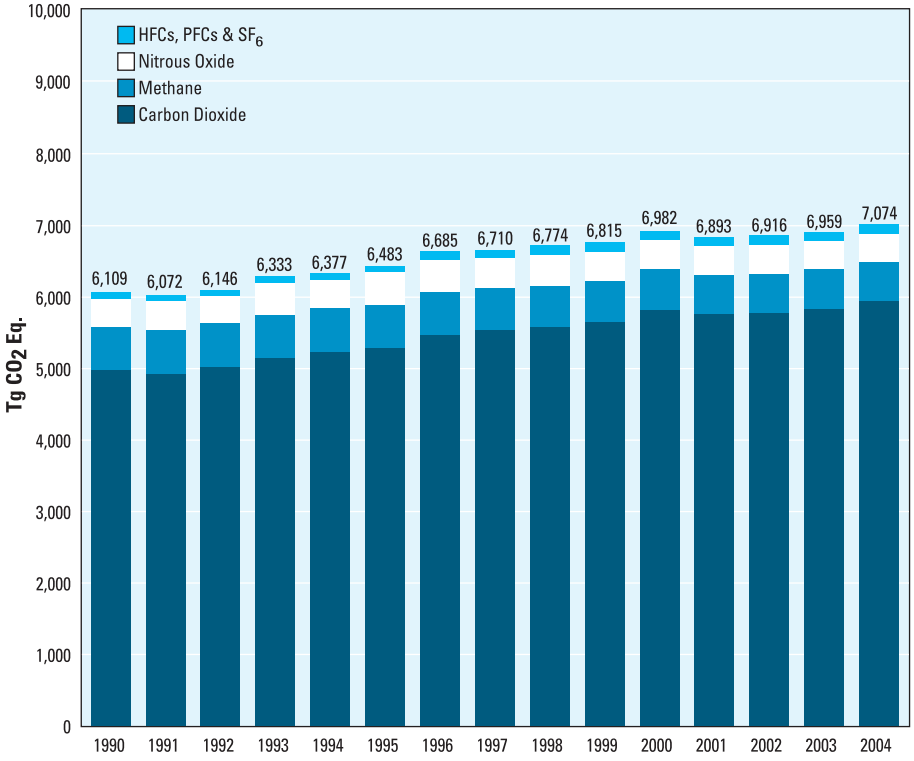


FIGURE 3-2 Annual Percent Change in U.S. Greenhouse Gas Emissions

Between 2003 and 2004, U.S. greenhouse gas emissions rose by 1.7 percent; the average annual rate increase from 1990 through 2004 was also 1.1 percent.

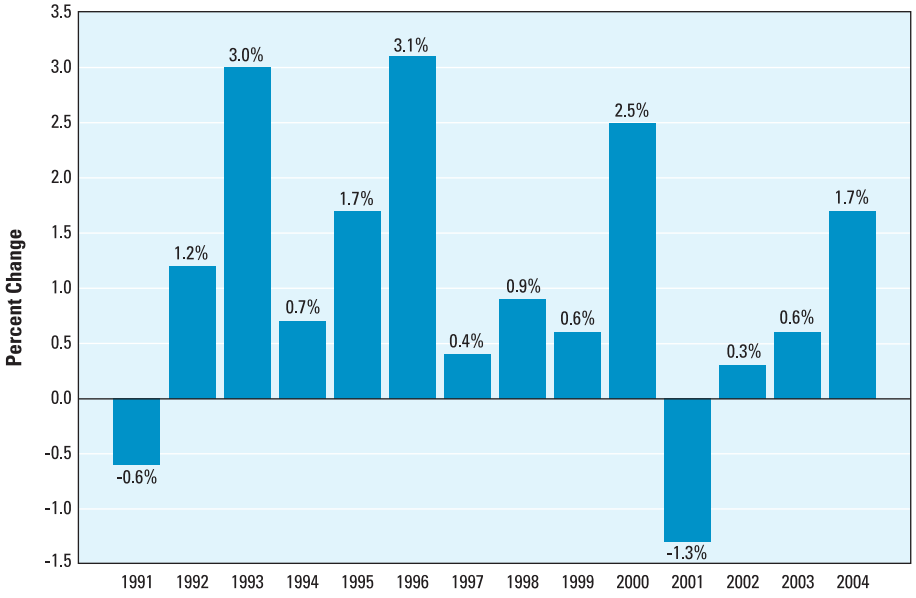


FIGURE 3-3 Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990

From 1990 to 2004, total U.S. greenhouse gas emissions rose by 965.4 Tg CO_2 Eq., an increase of 15.8 percent.

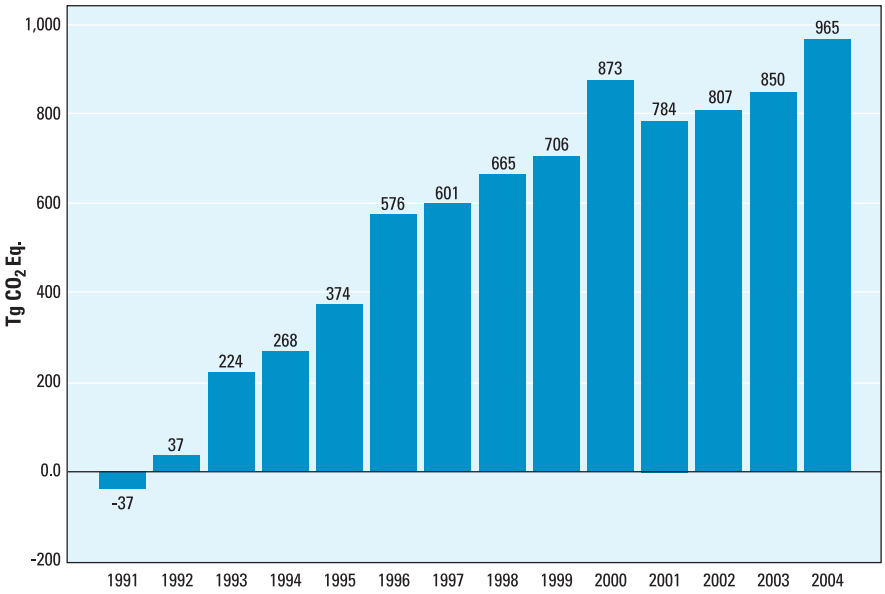
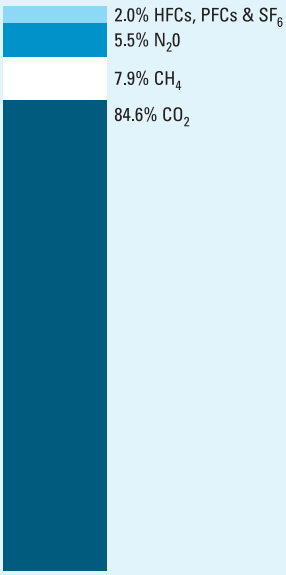


FIGURE 3-4 2004 U.S. Greenhouse Gas Emissions by Gas

The principal greenhouse gas emitted by human activities in 2004 was CO_2, driven primarily by emissions from fossil fuel combustion.



emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. Electrical transmission and distribution systems accounted for most SF_6 emissions, while PFC emissions resulted from semiconductor manufacturing and as a by-product of primary aluminum production.

Overall, from 1990 through 2004, total emissions of CO_2 increased by 982.7 Tg CO_2 Eq. (20 percent), while CH_4 and N_2O emissions decreased by 61.3 Tg CO_2 Eq. (10 percent) and 8.2 Tg CO_2 Eq. (2 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 52.2 Tg CO_2 Eq. (58 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high GWPs and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings and food scraps, which, in aggregate, offset 11 percent of total emissions in 2004. The following sections describe each gas's contribution to total U.S. greenhouse gas emissions in more detail.

Carbon Dioxide Emissions

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly balanced. Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen about 35 percent (IPCC 2001a; Hofmann 2004), principally due to the combustion of fossil fuels. Within the United States, fuel combustion accounted for 94 percent of CO_2 emissions in 2004 (Figure 3-5 and Table 3-3). Globally, approximately 25,575 Tg of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2002, of which the United States accounted for about 23 percent.[6] Changes in land use and forestry practices can also emit CO_2 (e.g., through conversion of forest land to agricultural or urban use) or can act as a sink for CO_2 (e.g., through net additions to forest biomass)

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 80 percent of GWP-weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2004. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 through 2004. The fundamental factors influencing this trend include a generally growing domestic economy over the last 14 years, and significant growth in emissions from transportation activities and electricity generation. Between 1990 and 2004, CO_2 emissions from fossil fuel combustion increased from 4,696.6 Tg

[6] Global CO_2 emissions from fossil fuel combustion were taken from Marland et al. 2005 <http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm>.

TABLE 3-2 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2 Eq.)

From 1990 through 2004, U.S. greenhouse gas emissions increased by 15.8 percent. Specifically, CO_2 emissions increased by 20 percent; CH_4 and N_2O emissions decreased by 10 and 2 percent, respectively; and HFC, PFC, and SF_6 emissions increased by 58 percent.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
CO_2	**5,005.3**	**5,620.2**	**5,695.0**	**5,864.5**	**5,795.2**	**5,815.9**	**5,877.7**	**5,988.0**
Fossil Fuel Combustion	4,696.6	5,271.8	5,342.4	5,533.7	5,486.9	5,501.8	5,571.1	5,656.6
Nonenergy Use of Fuels	117.2	152.8	160.6	140.7	131.0	136.5	133.5	153.4
Iron and Steel Production	85.0	67.7	63.8	65.3	57.8	54.6	53.3	51.3
Cement Manufacture	33.3	39.2	40.0	41.2	41.4	42.9	43.1	45.6
Waste Combustion	10.9	17.1	17.6	17.9	18.6	18.9	19.4	19.4
Ammonia Production and Urea Application	19.3	21.9	20.6	19.6	16.7	18.5	15.3	16.9
Lime Manufacture	11.2	13.9	13.5	13.3	12.8	12.3	13.0	13.7
Limestone and Dolomite Use	5.5	7.4	8.1	6.0	5.7	5.9	4.7	6.7
Natural Gas Flaring	5.8	6.6	6.9	5.8	6.1	6.2	6.1	6.0
Aluminum Production	7.0	6.4	6.5	6.2	4.5	4.6	4.6	4.3
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.2	4.1	4.1	4.1	4.2
Petrochemical Production	2.2	3.0	3.1	3.0	2.8	2.9	2.8	2.9
Titanium Dioxide Production	1.3	1.8	1.9	1.9	1.9	2.0	2.0	2.3
Phosphoric Acid Production	1.5	1.6	1.5	1.4	1.3	1.3	1.4	1.4
Ferroalloy Production	2.0	2.0	2.0	1.7	1.3	1.2	1.2	1.3
CO_2 Consumption	0.9	0.9	0.8	1.0	0.8	1.0	1.3	1.2
Zinc Production	0.9	1.1	1.1	1.1	1.0	0.9	0.5	0.5
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Consumption	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[a]	*(910.4)*	*(744.0)*	*(765.7)*	*(759.5)*	*(768.0)*	*(768.6)*	*(774.8)*	*(780.1)*
International Bunker Fuels[b]	*113.5*	*114.6*	*105.2*	*101.4*	*97.8*	*89.5*	*84.1*	*94.5*
Wood Biomass and Ethanol Combustion[b]	*216.7*	*217.2*	*222.3*	*226.8*	*200.5*	*194.4*	*202.1*	*211.2*
CH_4	**618.1**	**579.5**	**569.0**	**566.9**	**560.3**	**559.8**	**564.4**	**556.7**
Landfills	172.3	144.4	141.6	139.0	136.2	139.8	142.4	140.9
Natural Gas Systems	126.7	125.4	121.7	126.7	125.6	125.4	124.7	118.8
Enteric Fermentation	117.9	116.7	116.8	115.6	114.6	114.7	115.1	112.6
Coal Mining	81.9	62.8	58.9	56.3	55.5	52.5	54.8	56.3
Manure Management	31.2	38.8	38.1	38.0	38.9	39.3	39.2	39.4
Wastewater Treatment	24.8	32.6	33.6	34.3	34.7	35.8	36.6	36.9
Petroleum Systems	34.4	29.7	28.5	27.8	27.4	26.8	25.9	25.7
Rice Cultivation	7.1	7.9	8.3	7.5	7.6	6.8	6.9	7.6
Stationary Sources	7.9	6.8	7.0	7.3	6.6	6.2	6.5	6.4
Abandoned Coal Mines	6.0	6.9	6.9	7.2	6.6	6.0	5.8	5.6
Mobile Sources	4.7	3.8	3.6	3.5	3.3	3.2	3.0	2.9
Petrochemical Production	1.2	1.7	1.7	1.7	1.4	1.5	1.5	1.6
Iron and Steel Production	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0
Agricultural Residue Burning	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.9
Silicon Carbide Production	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*

TABLE 3-2 (Continued) **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2 Eq.)

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
N_2O	**394.9**	**440.6**	**419.4**	**416.2**	**412.8**	**407.4**	**386.1**	**386.7**
Agricultural Soil Management	266.1	301.1	281.2	278.2	282.9	277.8	259.2	261.5
Mobile Sources	43.5	54.8	54.1	53.1	50.0	47.5	44.8	42.8
Manure Management	16.3	17.4	17.4	17.8	18.1	18.0	17.5	17.7
Nitric Acid Production	17.8	20.9	20.1	19.6	15.9	17.2	16.7	16.6
Human Sewage	12.9	14.9	15.4	15.5	15.6	15.6	15.8	16.0
Stationary Sources	12.3	13.4	13.4	13.9	13.5	13.2	13.6	13.7
Settlements Remaining Settlements	5.6	6.2	6.2	6.0	5.8	6.0	6.2	6.4
Adipic Acid Production	15.2	6.0	5.5	6.0	4.9	5.9	6.2	5.7
N_2O Product Usage	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Waste Combustion	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Agricultural Residue Burning	0.4	0.5	0.4	0.5	0.5	0.4	0.4	0.5
Forest Land Remaining Forest Land	0.1	0.4	0.5	0.4	0.4	0.4	0.4	0.4
International Bunker Fuels[b]	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*
HFCs, PFCs, and SF_6	**90.8**	**133.4**	**131.5**	**134.7**	**124.9**	**132.7**	**131.0**	**143.0**
Substitution of Ozone-Depleting Substances	0.4	54.5	62.8	71.2	78.6	86.2	93.5	103.3
HCFC-22 Production	35.0	40.1	30.4	29.8	19.8	19.8	12.3	15.6
Electrical Transmission and Distribution	28.6	16.7	16.1	15.3	15.3	14.5	14.0	13.8
Semiconductor Manufacture	2.9	7.1	7.2	6.3	4.5	4.4	4.3	4.7
Aluminum Production	18.4	9.1	9.0	9.0	4.0	5.3	3.8	2.8
Magnesium Production and Processing	5.4	5.8	6.0	3.2	2.6	2.6	3.0	2.7
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

+ Does not exceed 0.05 Tg CO_2 Eq.
[a] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.
[b] Emissions from international bunker fuels and from wood biomass and ethanol combustion are not included in the totals.
Note: Totals may not sum due to independent rounding.

CO_2 Eq. to 5,656.6 Tg CO_2 Eq.—a 20 percent total increase over the 14-year period. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

From 2003 through 2004, emissions from fossil fuel combustion increased by 85.5 Tg CO_2 Eq. (1.5 percent). A number of factors played a major role in the magnitude of this increase. Strong growth in the U.S. economy and industrial production, particularly in energy-intensive industries, caused an increase in the demand for electricity and fossil fuels. Demand for travel was also higher, causing an increase in petroleum consumed for transportation. In contrast, the warmer winter conditions led to decreases in demand for heating fuels in the residential and commercial sectors. Moreover, much of the increased electricity demanded was generated by natural gas consumption and nuclear power, rather than by more carbon-intensive coal, moderating the increase in CO_2 emissions from electricity generation. Use of renewable fuels rose very slightly, due to increases in the use of biofuels. Figures 3-6 and 3-7 summarize CO_2 emissions from fossil fuel combustion by sector and fuel type and by end-use sector.

Other significant CO_2 trends included the following:

- CO_2 emissions from iron and steel production decreased to 51.3 Tg CO_2 Eq. in 2004, and declined by 33.7 Tg CO_2 Eq. (40 percent) from 1990 through 2004, due to reduced domestic production of pig iron, sinter, and coal coke.
- CO_2 emissions from cement production increased to 45.6 Tg CO_2 Eq. in 2004, a 37 percent increase in emissions since 1990. Emissions mirror growth in the construction industry. In contrast to many other manufacturing sectors, demand for domestic cement remains strong, because it is not cost-effective to transport cement far from its point of manufacture.
- CO_2 emissions from waste combustion (19.4 Tg CO_2 Eq. in 2004) increased by

TABLE 3-3 AND FIGURE 3-5 **2004 U.S. Sources of CO_2** ($Tg\ CO_2$ Eq.)

In 2004, CO_2 accounted for 84.6 percent of U.S. greenhouse gas emissions. Between 1990 and 2004, CO_2 emissions from fossil fuel combution increased at an average annual rate of 1.3 percent and grew by 20.4 percent over the 14-year period.

Sources	1990	1998	1999	2000	2001	2002	2003	2004
Fossil Fuel Combustion	4,696.6	5,271.8	5,342.4	5,533.7	5,486.9	5,501.8	5,571.1	5,656.6
Nonenergy Use of Fuels	117.2	152.8	160.6	140.7	131.0	136.5	133.5	153.4
Iron and Steel Production	85.0	67.7	63.8	65.3	57.8	54.6	53.3	51.3
Cement Manufacture	33.3	39.2	40.0	41.2	41.4	42.9	43.1	45.6
Waste Combustion	10.9	17.1	17.6	17.9	18.6	18.9	19.4	19.4
Ammonia Production and Urea Application	19.3	21.9	20.6	19.6	16.7	18.5	15.3	16.9
Lime Manufacture	11.2	13.9	13.5	13.3	12.8	12.3	13.0	13.7
Limestone and Dolomite Use	5.5	7.4	8.1	6.0	5.7	5.9	4.7	6.7
Natural Gas Flaring	5.8	6.6	6.9	5.8	6.1	6.2	6.1	6.0
Aluminum Production	7.0	6.4	6.5	6.2	4.5	4.6	4.6	4.3
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.2	4.1	4.1	4.1	4.2
Petrochemical Production	2.2	3.0	3.1	3.0	2.8	2.9	2.8	2.9
Titanium Dioxide Production	1.3	1.8	1.9	1.9	1.9	2.0	2.0	2.3
Phosphoric Acid Production	1.5	1.6	1.5	1.4	1.3	1.3	1.4	1.4
Ferroalloy Production	2.0	2.0	2.0	1.7	1.3	1.2	1.2	1.3
CO_2 Consumption	0.9	0.9	0.8	1.0	0.8	1.0	1.3	1.2
Zinc Production	0.9	1.1	1.1	1.1	1.0	0.9	0.5	0.5
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Consumption	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[a]	*(910.4)*	*(744.0)*	*(765.7)*	*(759.5)*	*(768.0)*	*(768.6)*	*(774.8)*	*(780.1)*
International Bunker Fuels[b]	*113.5*	*114.6*	*105.2*	*101.4*	*97.8*	*89.5*	*84.1*	*94.5*
Wood Biomass and Ethanol Combustion[b]	*216.7*	*217.2*	*222.3*	*226.8*	*200.5*	*194.4*	*202.1*	*211.2*
Total	**5,005.3**	**5,620.2**	**5,695.0**	**5,864.5**	**5,795.2**	**5,815.9**	**5,877.7**	**5,988.0**

[a] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in separate net emissions totals.

[b] Emissions from international bunker fuels and from wood biomass and ethanol combustion are not included in the totals.

Note: Totals may not sum due to independent rounding.

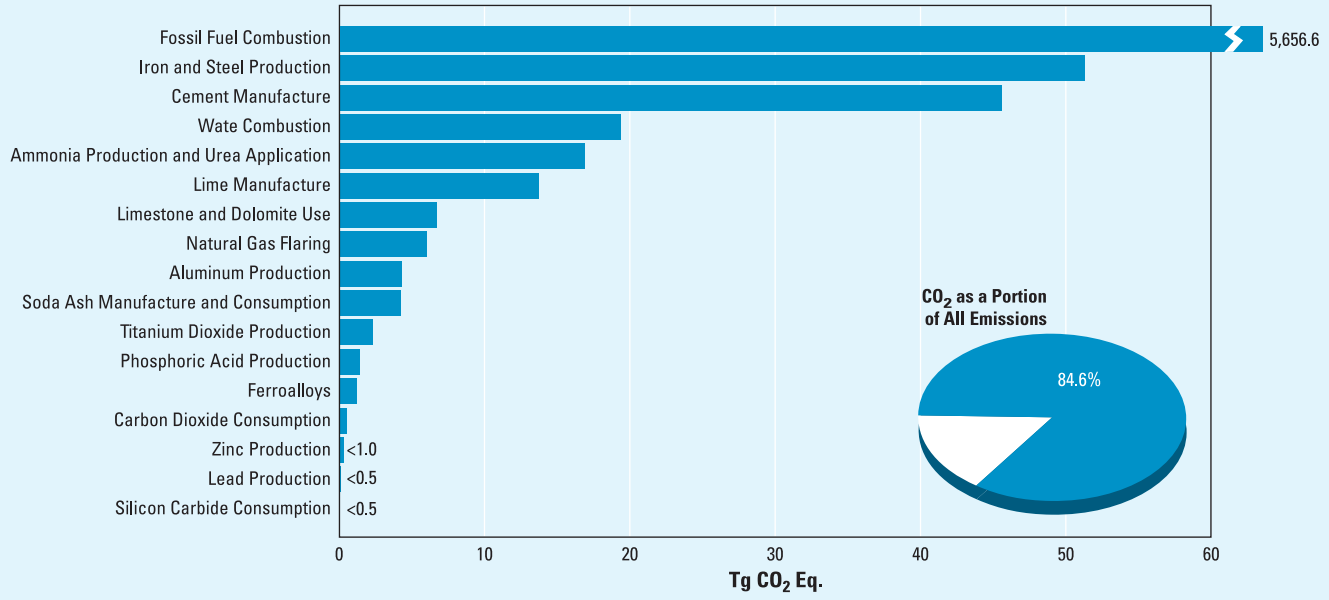
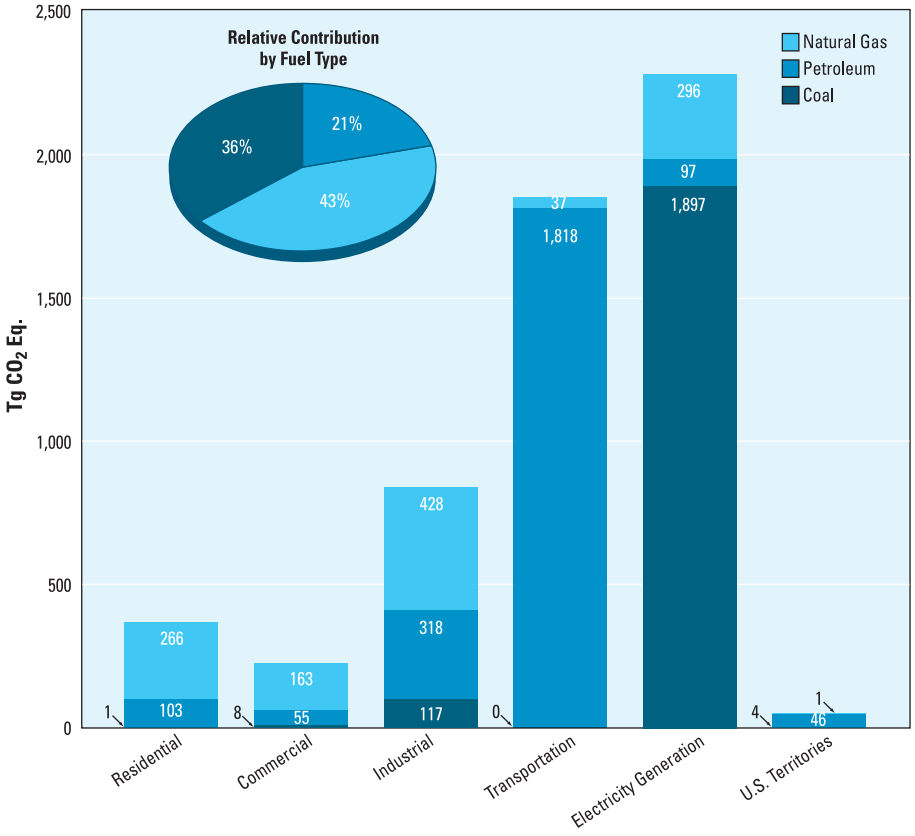


FIGURE 3-6 **2004 U.S. CO_2 Emissions From Fossil Fuel Combustion by Sector and Fuel Type**

Of the emissions from fossil fuel combustion in 2004, transportation sector emissions were primarily from petroleum consumption, while electricity generation emissions were primarily from coal consumption.



Note: Electricity generation also includes emissions of less than 1 Tg CO_2 Eq. from geothermal-based electricity generation.

8.4 Tg CO_2 Eq. (77 percent) from 1990 through 2004, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

- Net CO_2 sequestration from land use, land-use change, and forestry decreased by 130.3 Tg CO_2 Eq. (14 percent) from 1990 through 2004. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. Annual carbon accumulation in landfilled yard trimmings and food scraps also slowed over this period, while the rate of carbon accumulation in agricultural soils and urban trees increased.

Methane Emissions

According to the IPCC, CH_4 is more than 20 times as effective as CO_2 at trapping heat in the atmosphere. Over the last 250 years, the concentration of CH_4 in the atmosphere increased by 143 percent (IPCC 2001a; Hofmann 2004). Anthropogenic emission sources of CH_4 include landfills, natural gas and petroleum systems, agricultural activities, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (Figure 3-8 and Table 3-4).

Some significant trends in U.S. emissions of CH_4 include the following:

- Landfills are the largest anthropogenic source of CH_4 emissions in the United States. In 2004, landfill CH_4 emissions were 140.9 Tg CO_2 Eq. (approximately 25 percent of total CH_4 emissions), which represents a decline of 31.4 Tg CO_2 Eq., or 18 percent, since 1990. Although the amount of solid waste landfilled each year continues to climb, the amount of CH_4 captured and burned at landfills has increased dramatically, countering this trend.
- CH_4 emissions from natural gas systems were 118.8 Tg CO_2 Eq. in 2004; emissions have declined by 7.9 Tg CO_2 Eq. (6 percent) since 1990. This decline has been due to improvements in technology and management practices, as well as some replacement of old equipment.
- Enteric fermentation was also a significant source of CH_4, accounting for 112.6 Tg CO_2 Eq. in 2004. This amount has declined by 5.3 Tg CO_2 Eq. (4 percent) since 1990, and by 10.4 Tg CO_2 Eq. (8 percent) from a high in 1995. Generally, emissions have been decreasing since 1995, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle.

Nitrous Oxide Emissions

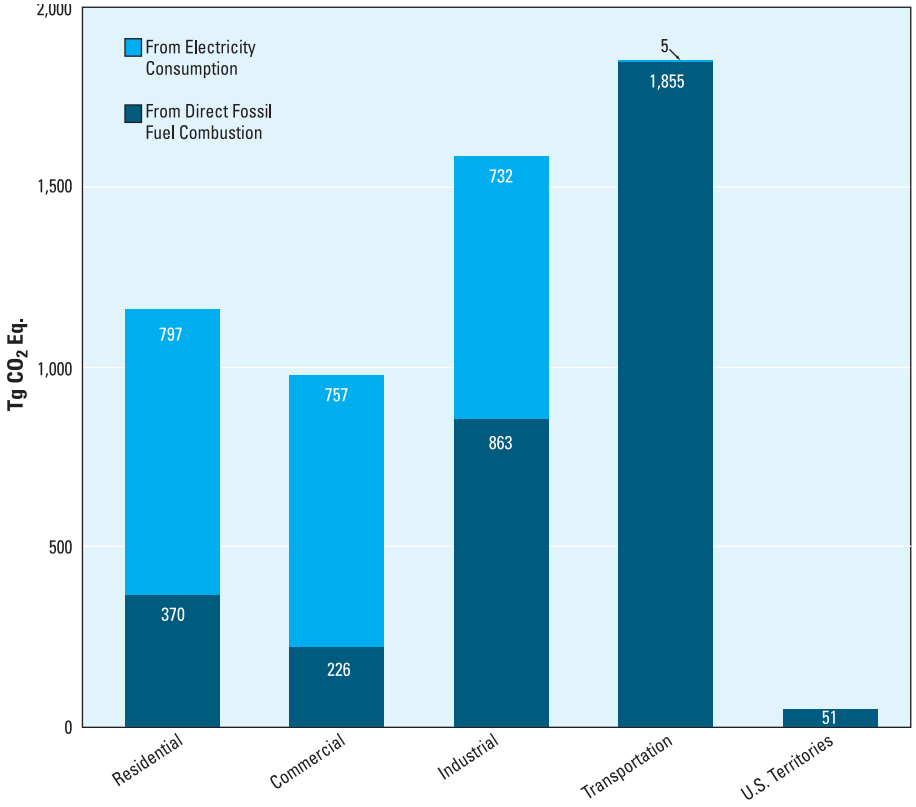
Nitrous oxide is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 300 times more powerful than CO_2 at trapping heat in the atmosphere. Since 1750, the global atmospheric concentration of N_2O has risen by approximately 18 percent (IPCC 2001a; Hofmann 2004). The main anthropogenic activities producing N_2O in the United States are agricultural soil management, fuel combustion in motor vehicles, manure management, nitric acid production, human sewage, and stationary fuel combustion (Figure 3-9 and Table 3-5).

Some significant trends in U.S. emissions of N_2O include the following:

- Agricultural soil management activities, such as fertilizer application and other

FIGURE 3-7 **2004 U.S. End-Use Sector Emissions of CO_2 From Fossil Fuel Combustion**

In 2004, most commercial and residential emissions were from these sectors' use of electricity. The transportation sector has small emissions associated with electricity use.



cropping practices, were the largest source of U.S. N_2O emissions, accounting for 68 percent (261.5 Tg CO_2 Eq.) of 2004 emissions. N_2O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to such factors as temperature and precipitation, which have generally outweighed changes in the amount of nitrogen applied to soils.

- In 2004, N_2O emissions from mobile combustion were 42.8 Tg CO_2 Eq. (approximately 11 percent of U.S. N_2O emissions). From 1990 through 2004, N_2O emissions from mobile combustion decreased by 1 percent. However, from 1990 through 1998, emissions increased by 26 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer control technologies have led to a steady decline in N_2O emissions from this source.

HFC, PFC, and SF_6 Emissions

HFCs and PFCs are families of synthetic chemicals that are being used as alternatives to ODSs, which are being phased out under the *Montreal Protocol* and Clean Air Act Amendments of 1990. HFCs and PFCs do not deplete the stratospheric ozone layer, and are therefore acceptable alternatives under the *Montreal Protocol*.

These compounds, however, along with SF_6, are potent greenhouse gases. In addition to having high GWPs, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. SF_6 is the most potent greenhouse gas the IPCC has evaluated.

Other emissive sources of these gases include HCFC-22 production, electrical transmission and distribution systems, semiconductor manufacturing, aluminum production, and magnesium production and processing (Figure 3-10 and Table 3-6).

Some significant trends in U.S. HFC, PFC, and SF_6 emissions include the following:

- Emissions resulting from the substitution of ODSs (e.g., CFCs) have been increasing from small amounts in 1990 to 103.3 Tg CO_2 Eq. in 2004. Emissions from ODS substitutes are both the largest and the fastest growing source of HFC, PFC, and SF_6 emissions. These emissions have been increasing as phase-outs required under the *Montreal Protocol* come into effect, especially after 1994, when full market penetration was made for the first generation of new technologies featuring ODS substitutes.
- The increase in ODS substitute emissions is offset substantially by decreases in emissions of HFCs, PFCs, and SF_6 from other sources. Emissions from aluminum production decreased by 85 percent (15.6 Tg CO_2 Eq.) from 1990 through 2004, due to both industry emission reduction efforts and lower domestic aluminum production.
- Emissions from the production of HCFC-22 decreased by 55 percent (19.4 Tg CO_2 Eq.) from 1990 through 2004, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions.
- Emissions from electric power transmission and distribution systems decreased by 52 percent (14.8 Tg CO_2 Eq.) from 1990 through 2004, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.

TABLE 3-4 AND FIGURE 3-8 **2004 U.S. Sources of CH_4** (Tg CO_2 Eq.)

Methane accounted for 7.9 percent of U.S. greenhouse gas emissions in 2004. Landfills were the largest anthropogenic source of CH_4, representing 25 percent of total U.S. CH_4 emissions.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Landfills	172.3	144.4	141.6	139.0	136.2	139.8	142.4	140.9
Natural Gas Systems	126.7	125.4	121.7	126.7	125.6	125.4	124.7	118.8
Enteric Fermentation	117.9	116.7	116.8	115.6	114.6	114.7	115.1	112.6
Coal Mining	81.9	62.8	58.9	56.3	55.5	52.5	54.8	56.3
Manure Management	31.2	38.8	38.1	38.0	38.9	39.3	39.2	39.4
Wastewater Treatment	24.8	32.6	33.6	34.3	34.7	35.8	36.6	36.9
Petroleum Systems	34.4	29.7	28.5	27.8	27.4	26.8	25.9	25.7
Rice Cultivation	7.1	7.9	8.3	7.5	7.6	6.8	6.9	7.6
Stationary Sources	7.9	6.8	7.0	7.3	6.6	6.2	6.5	6.4
Abandoned Coal Mines	6.0	6.9	6.9	7.2	6.6	6.0	5.8	5.6
Mobile Sources	4.7	3.8	3.6	3.5	3.3	3.2	3.0	2.9
Petrochemical Production	1.2	1.7	1.7	1.7	1.4	1.5	1.5	1.6
Iron and Steel Production	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0
Agricultural Residue Burning	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.9
Silicon Carbide Production	+	+	+	+	+	+	+	+
*International Bunker Fuels**	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
TOTAL	**618.1**	**579.5**	**569.0**	**566.9**	**560.3**	**559.8**	**564.4**	**556.7**

+ Does not exceed 0.05 Tg CO_2 Eq.
* Emissions from international bunker fuels are not included in the totals.

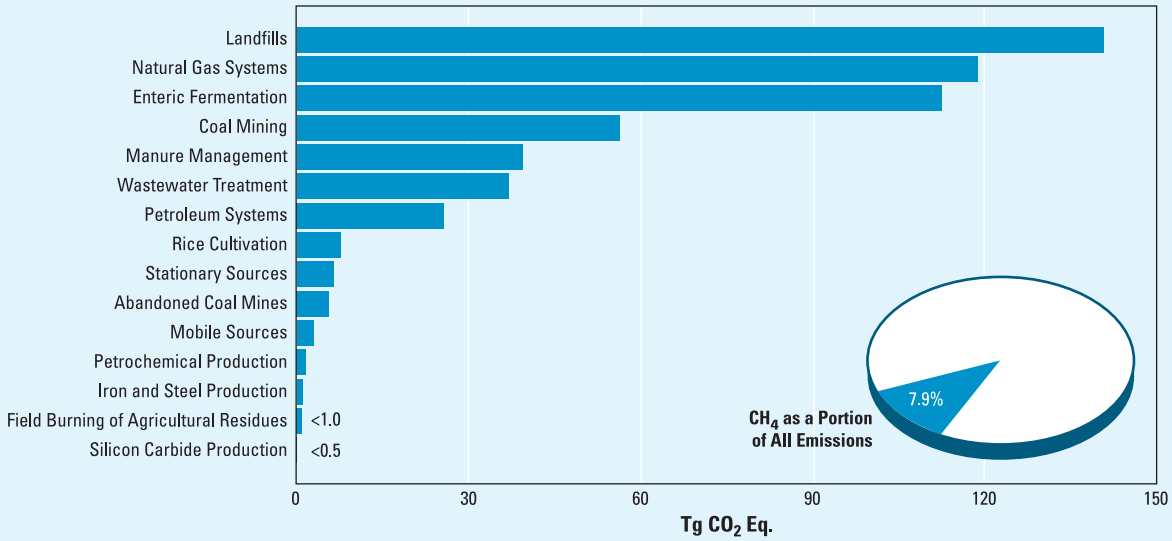
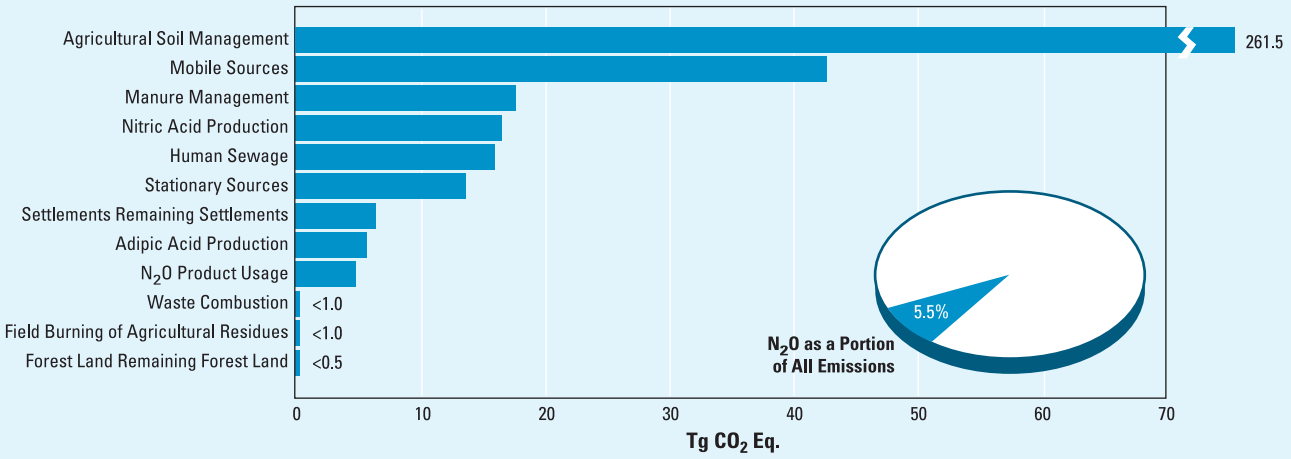


TABLE 3-5 AND FIGURE 3-9 **2004 U.S. Sources of N_2O** (Tg CO_2 Eq.)

Nitrous oxide accounted for 5.5 percent of U.S. greenhouse gas emissions in 2004. Agricultural soil management was the largest source of N_2O, representing approximately 60 percent of total N_2O emissions in 2004.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Agricultural Soil Management	266.1	301.1	281.2	278.2	282.9	277.8	259.2	261.5
Mobile Sources	43.5	54.8	54.1	53.1	50.0	47.5	44.8	42.8
Manure Management	16.3	17.4	17.4	17.8	18.1	18.0	17.5	17.7
Nitric Acid Production	17.8	20.9	20.1	19.6	15.9	17.2	16.7	16.6
Human Sewage	12.9	14.9	15.4	15.5	15.6	15.6	15.8	16.0
Stationary Sources	12.3	13.4	13.4	13.9	13.5	13.2	13.6	13.7
Settlements Remaining Settlements	5.6	6.2	6.2	6.0	5.8	6.0	6.2	6.4
Adipic Acid Production	15.2	6.0	5.5	6.0	4.9	5.9	6.2	5.7
N_2O Product Usage	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Waste Combustion	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Agricultural Residue Burning	0.4	0.5	0.4	0.5	0.5	0.4	0.4	0.5
Forest Land Remaining Forest Land	0.1	0.4	0.5	0.4	0.4	0.4	0.4	0.4
*International Bunker Fuels**	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*
Total	**394.9**	**440.6**	**419.4**	**416.2**	**412.8**	**407.4**	**386.1**	**386.7**

* Emissions from international bunker fuels are not included in the totals.
Note: Totals may not sum due to independent rounding.



OVERVIEW OF SECTOR EMISSIONS AND TRENDS

In accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997) and the *2003 UNFCCC Guidelines on Reporting and Review* (UNFCCC 2003), the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006a) is segregated into six sector-specific chapters. Figure 3-11 and Table 3-7 aggregate emissions and sinks by these chapters.

Energy

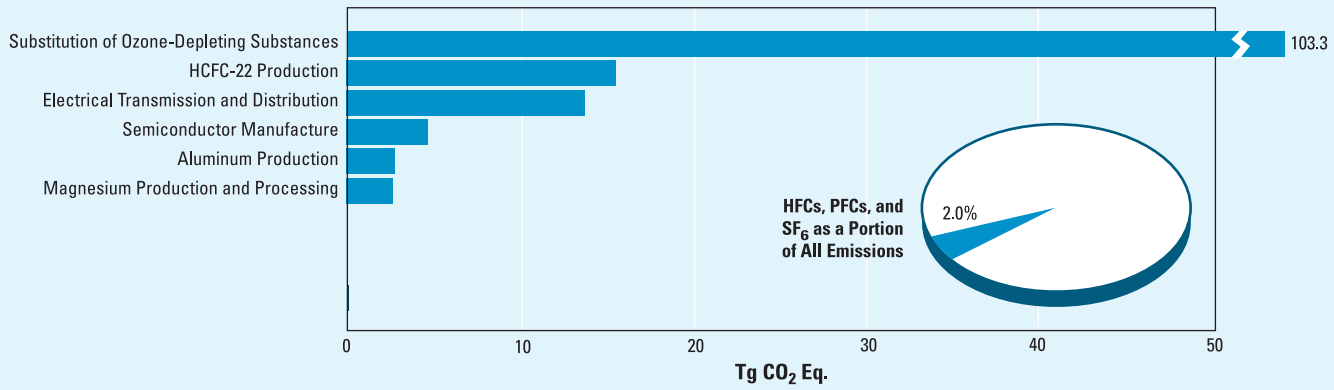
The Energy sector contains emissions of all greenhouse gases resulting from stationary and mobile energy activities, including fuel combustion and fugitive fuel emissions. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions from 1990 through 2004. In 2004, approximately 86 percent of the energy consumed in the United States was produced through the combustion of fossil fuels. The remaining 14 percent came from other energy sources, such as hydropower, biomass, nuclear, wind, and solar energy (Figure 3-12). Energy-related activities are also responsible for CH_4 and N_2O emissions (39 percent and 15 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy sector accounted for a combined 86 percent of total U.S. greenhouse gas emissions in 2004.

TABLE 3-6 AND FIGURE 3-10 **2004 U.S. Sources of HFCs, PFCs, SF_6 ($Tg\ CO_2$ Eq.)**

Because HFCs and PFCs do not deplete the stratospheric ozone layer, they are acceptable alternatives under the *Montreal Protocol*. However, these compounds, along with SF_6, have high global warming potentials, and SF_6 and PFCs have extremely long atmospheric lifetimes.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Substitution of Ozone-Depleting Substances	0.4	54.5	62.8	71.2	78.6	86.2	93.5	103.3
HCFC-22 Production	35.0	40.1	30.4	29.8	19.8	19.8	12.3	15.6
Electrical Transmission and Distribution	28.6	16.7	16.1	15.3	15.3	14.5	14.0	13.8
Semiconductor Manufacture	2.9	7.1	7.2	6.3	4.5	4.4	4.3	4.7
Aluminum Production	18.4	9.1	9.0	9.0	4.0	5.3	3.8	2.8
Magnesium Production and Processing	5.4	5.8	6.0	3.2	2.6	2.6	3.0	2.7
Net Emissions (Sources and Sinks)	**90.8**	**133.4**	**131.5**	**134.7**	**124.9**	**132.7**	**131.0**	**143.0**

Note: Totals may not sum due to independent rounding.



Industrial Processes

The Industrial Processes sector contains by-product or fugitive emissions of greenhouse gases from industrial processes not directly related to energy activities, such as fossil fuel combustion. For example, industrial processes can chemically transform raw materials, which often release waste gases, such as CO_2, CH_4, and N_2O. The processes include iron and steel production, lead and zinc production, cement manufacture, ammonia manufacture and urea application, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, aluminum production, petrochemical production, silicon carbide production, nitric acid production, and adipic acid production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF_6. Overall, emission sources in the Industrial Process sector accounted for 4.5 percent of U.S. greenhouse gas emissions in 2004.

Solvent and Other Product Use

The Solvent and Other Product Use sector contains greenhouse gas emissions that are produced as a by-product of various solvent and other product uses. In 2004, U.S. emissions from N_2O Product Usage, the only source of greenhouse gas emissions from this sector, accounted for less than 0.1 percent of total U.S. anthropogenic greenhouse gas emissions on a carbon equivalent basis.

Agriculture

The Agriculture sector contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy sector). Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. In 2004, CH_4 emissions from enteric fermentation and manure management represented about 20 percent and 7 percent of total CH_4 emissions from anthropogenic activities, respectively. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N_2O emissions in 2004, accounting for 68 percent. In 2004, emission sources accounted for in the Agriculture sector were responsible for 6.2 percent of total U.S. greenhouse gas emissions.

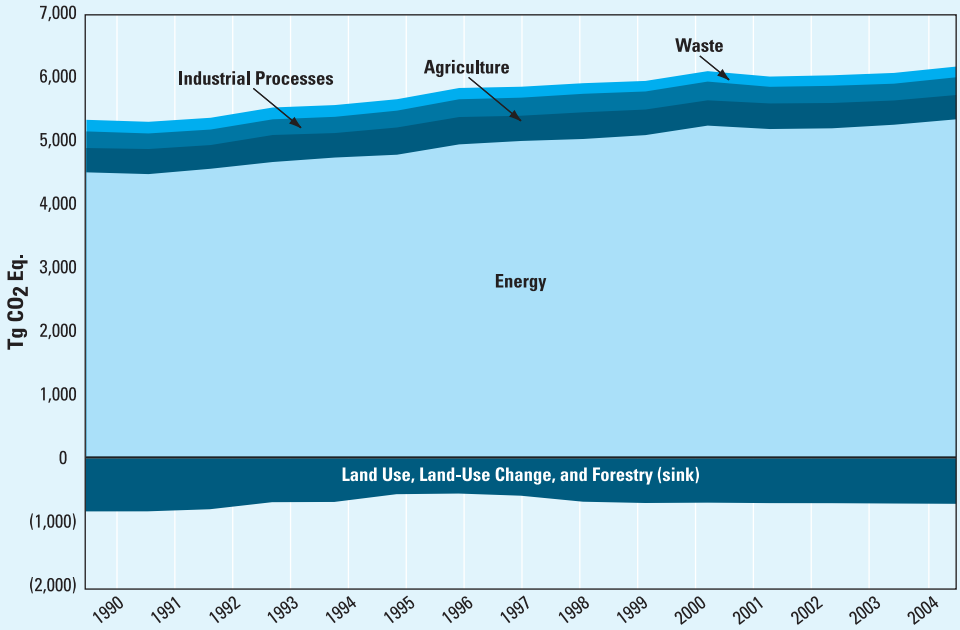
TABLE 3-7 AND FIGURE 3-11 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector** (Tg CO_2 Eq.)

In accordance with the IPCC Guidelines, the U.S. greenhouse gas inventory is segregated into six sector-specific chapters.

IPCC Sector	1990	1998	1999	2000	2001	2002	2003	2004
Energy	5,148.3	5,752.3	5,822.3	5,994.3	5,931.6	5,944.6	6,009.8	6,108.2
Industrial Processes	301.1	335.1	327.5	329.6	300.7	310.9	304.1	320.7
Solvent and Other Product Use	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Agriculture	439.6	483.2	463.1	458.4	463.4	457.8	439.1	440.1
Land Use, Land-Use Change, and Forestry (Emissions)	5.7	6.5	6.7	6.4	6.2	6.4	6.6	6.8
Waste	210.0	191.8	190.7	188.8	186.4	191.3	194.8	193.8
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry*	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

* Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.

Note: Totals may not sum due to independent rounding.

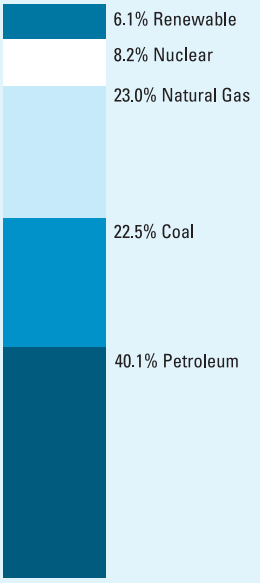


Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry sector contains emissions and removals of CO_2 from forest management, other land-use activities, and land-use change. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in a net uptake (sequestration) of carbon in the United States. Forests (including vegetation, soils, and harvested wood) accounted for approximately 82 percent of total 2004 sequestration; urban trees accounted for 11 percent; agricultural soils (including mineral and organic soils and the application of lime) accounted for 6 percent; and landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2004. The net forest sequestration is a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils, mineral soils account for a net carbon sink that is almost two times larger than the sum of emissions from organic soils and liming. The mineral soil carbon sequestration is largely due to the conversion of cropland to permanent

FIGURE 3-12 **U.S. Energy Consumption by Energy Source**

In 2004, the combustion of fossil fuels accounted for approximately 86 percent of U.S. energy consumption. Hydropower, biomass, nuclear, wind, and solar energy made up the remaining 14 percent.



pastures and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard-trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2004 resulted in a net carbon sequestration of 780.1 Tg CO_2 Eq. (Table 3-7). This represents an offset of approximately 13 percent of total U.S. CO_2 emissions, or 11 percent of total greenhouse gas emissions in 2004. Total land use, land-use change, and forestry net carbon sequestration declined by approximately 14 percent from 1990 through 2004, which contributed to an increase in net U.S. emissions (all sources and sinks) of 21 percent from 1990 through 2004. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks, as forests mature. Annual carbon accumulation in landfilled yard trimmings and food scraps and agricultural soils also slowed over this period. However, the rate of annual carbon accumulation increased in both agricultural soils and urban trees.

Land use, land-use change, and forestry activities in 2004 also resulted in emissions of N_2O (6.8 Tg CO_2 Eq.). Total N_2O emissions from the application of fertilizers to forests and settlements increased by approximately 20 percent from 1990 through 2004.

Waste

The Waste sector contains emissions from waste management activities (except waste incineration, which is addressed in the Energy sector). Landfills were the largest source of anthropogenic CH_4 emissions, accounting for 25 percent of total U.S. CH_4 emissions.[7] Additionally, wastewater treatment accounts for 7 percent of U.S. CH_4 emissions. N_2O emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N_2O emissions from the treatment process itself, using a simplified methodology. Wastewater treatment systems are a potentially significant source of N_2O emissions; however, methodologies are not currently available to develop a complete estimate. N_2O emissions from the treatment of the human sewage component of wastewater were estimated, however, using a simplified methodology. Overall, in 2004, emission sources accounted for in the Waste sector generated 2.7 percent of total U.S. greenhouse gas emissions.

EMISSIONS BY ECONOMIC SECTOR

Emission estimates, for the purposes of inventory reports, are grouped into six sectors defined by the IPCC: Energy, Industrial Processes, Solvent Use, Agriculture, Land-Use Change and Forestry, and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following economic sectors: Residential, Commercial, Industry, Transportation, Electricity Generation, and Agriculture, and U.S. Territories. Table 3-8 summarizes emissions from each of these sectors, and Figure 3-13 shows emission trends by sector from 1990 through 2004.

Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2004; transportation activities, in aggregate, accounted for the second largest portion (28 percent). Emissions from industry accounted for 19 percent of U.S. greenhouse gas emissions in 2004. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade, although there was an increase in industrial emissions in 2004 (up 3 percent from 2003 levels). The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for about 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions; unlike other economic sectors, agriculture sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for about 7 percent of emissions, while U.S. territories accounted for 1 percent.

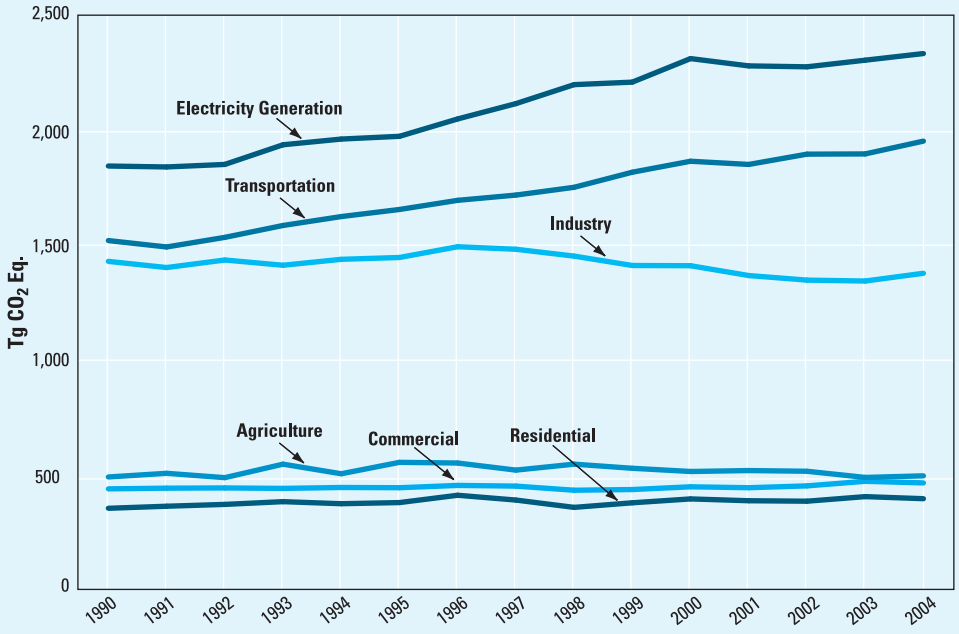
[7] Landfills also store carbon, resulting from incomplete degradation of organic materials, such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter of the national *Inventory* report.

TABLE 3-8 AND FIGURE 3-13 U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq.)

In 2004, U.S. greenhouse gas emissions from electricity generation accounted for one-third of total greenhouse gas emissions, and the transportation sector accounted for almost 28 percent.

Economic Sector	1990	1998	1999	2000	2001	2002	2003	2004
Electricity Generation	1,846.4	2,202.4	2,213.3	2,315.9	2,284.4	2,280.1	2,308.5	2,337.8
Transportation	1,520.3	1,753.4	1,819.3	1,866.9	1,852.7	1,898.0	1,898.9	1,955.1
Industry	1,438.9	1,452.4	1,411.0	1,409.7	1,366.6	1,346.7	1,342.7	1,377.3
Agriculture	486.3	541.6	523.9	509.5	514.4	511.0	484.2	491.3
Commercial	433.6	428.0	430.6	443.0	439.5	447.5	466.5	459.9
Residential	349.4	353.3	372.6	390.4	381.6	380.1	399.8	391.1
U.S. Territories	33.8	42.7	44.2	46.9	54.0	52.4	58.6	61.9
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Land Use, Land-Use Change, and Forestry	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

Notes:
Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.
Totals may not sum due to independent rounding. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.



Note: Does not include U.S. territories.

CO_2 was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Electricity is ultimately consumed in the economic sectors described above. Table 3-9 presents greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity.[8] These source categories include CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from waste combustion, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (30 percent) in 2004. Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (lighting, appliances, etc.). Transportation activities remain the second largest contributor to total U.S. emissions (28 percent). In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels. Figure 3-14 shows the trend in these emissions by sector from 1990 through 2004.

INDIRECT GREENHOUSE GASES

The reporting requirements of the UNFCCC[9] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (U.S. EPA 2005),[10] which are regulated under the Clean Air Act. Table 3-10 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Recalculations of Inventory Estimates

Each year, emission and sink estimates are recalculated and revised for all years in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, as attempts are made to improve both the analyses themselves, through the use of better methods or data, and the overall usefulness of the report. In this effort, the United States follows the IPCC *Good Practice Guidance* (IPCC 2000), which states, regarding recalculations of the time series, "It is good practice to recalculate historic emissions when methods are changed or refined, when new source categories are included in the national inventory, or when errors in the estimates are identified and corrected." In general, recalculations are made to the U.S. greenhouse gas emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data.

In each *Inventory* report, the results of all methodology changes and historical data updates are presented in the "Recalculations and Improvements" chapter; detailed descriptions of each recalculation are contained within each source's description contained in the report, if applicable. In general, when methodological changes have been implemented, the entire time series (in the case of the most recent *Inventory* report, 1990 through 2003) has been recalculated to reflect the change, per IPCC *Good Practice Guidance*. Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information. More information on the most recent changes is provided in the "Recalculations and Improvements" chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c), and previous *Inventory* reports can further describe the changes in calculation methods and data since the previous *Climate Action Report*.

[8] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

[9] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

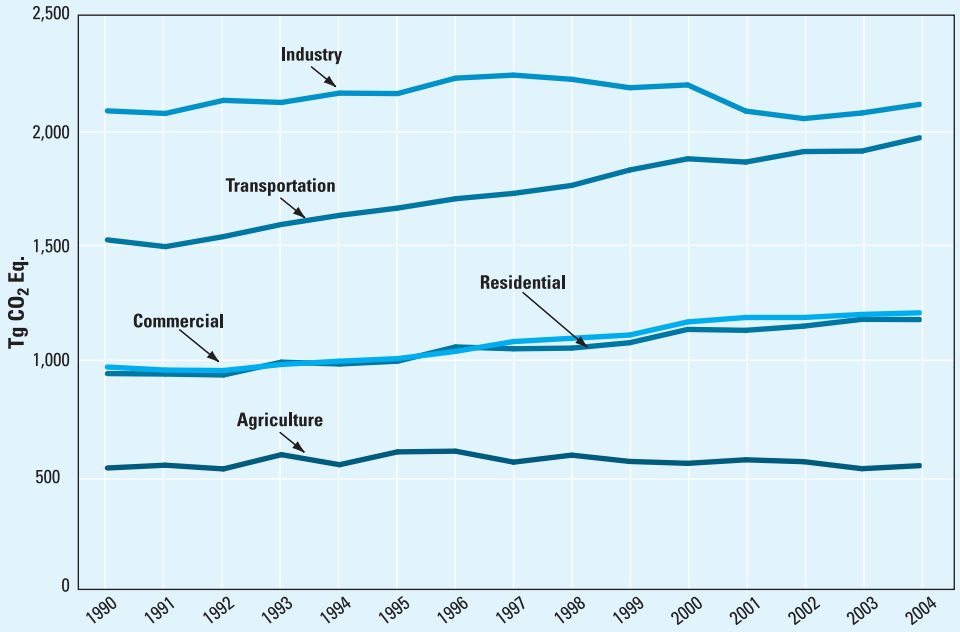
[10] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore were not taken from U.S. EPA 2005.

TABLE 3-9 AND FIGURE 3-14 U.S Electricity-Related Greenhouse Gas Emissions Distributed Among Economic Sectors (Tg CO_2 Eq.)

When 2004 U.S. greenhouse gas emissions from electricity generation were distributed among the economic sectors, industry accounted for the largest share (30 percent) and transportation, the second largest (28 percent).

Economic Sector	1990	1998	1999	2000	2001	2002	2003	2004
Industry	2,074.6	2,210.3	2,174.4	2,186.1	2,073.6	2,042.0	2,066.0	2,103.0
Transportation	1,523.4	1,756.5	1,822.5	1,870.3	1,856.2	1,901.4	1,903.2	1,959.8
Commercial	979.2	1,102.0	1,115.8	1,171.8	1,190.8	1,191.4	1,204.3	1,211.0
Residential	950.8	1,060.0	1,083.2	1,140.0	1,136.2	1,154.1	1,182.9	1,181.9
Agriculture	547.2	602.4	575.0	567.2	582.6	574.5	544.3	556.9
U.S. Territories	33.8	42.7	44.2	46.9	54.0	52.4	58.6	61.9
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Land Use, Land-Use Change, and Forestry	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

Note: Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.



Note: Does not include U.S. territories.

TABLE 3-10 **Emissions of Indirect Greenhouse Gases** (Gg)

Fuel combustion accounts for the majority of emissions of indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Gas/Activity	1990	1998	1999	2000	2001	2002	2003	2004
NO_x	**22,860**	**21,964**	**20,530**	**20,288**	**19,414**	**18,850**	**17,995**	**17,076**
Stationary Fossil Fuel Combustion	9,884	9,419	8,344	8,002	7,667	7,522	7,138	6,662
Mobile Fossil Fuel Combustion	12,134	11,592	11,300	11,395	10,823	10,389	9,916	9,465
Oil and Gas Activities	139	130	109	111	113	135	135	135
Waste Combustion	82	145	143	114	114	134	134	134
Industrial Processes	591	637	595	626	656	630	631	632
Solvent Use	1	3	3	3	3	6	6	6
Agricultural Burning	28	35	34	35	35	33	34	39
Waste	0	3	3	2	2	2	2	2
CO	**130,580**	**98,984**	**94,361**	**92,895**	**89,329**	**87,428**	**87,518**	**87,599**
Stationary Fossil Fuel Combustion	4,999	3,927	5,024	4,340	4,377	4,020	4,020	4,020
Mobile Fossil Fuel Combustion	119,482	87,940	83,484	83,680	79,972	78,574	78,574	78,574
Oil and Gas Activities	302	332	145	146	147	116	116	116
Waste Combustion	978	2,826	2,725	1,670	1,672	1,672	1,672	1,672
Industrial Processes	4,124	3,163	2,156	2,217	2,339	2,286	2,286	2,286
Solvent Use	4	1	46	46	45	46	46	46
Agricultural Burning	689	789	767	790	770	706	796	877
Waste	1	5	13	8	8	8	8	8
NMVOCs	**20,937**	**16,403**	**15,869**	**15,228**	**15,048**	**14,217**	**13,877**	**13,556**
Stationary Fossil Fuel Combustion	912	1,016	1,045	1,077	1,080	923	922	922
Mobile Fossil Fuel Combustion	10,933	7,742	7,586	7,230	6,872	6,560	6,212	5,882
Oil and Gas Activities	555	440	414	389	400	340	341	341
Waste Combustion	222	326	302	257	258	281	282	282
Industrial Processes	2,426	2,047	1,813	1,773	1,769	1,723	1,725	1,727
Solvent Use	5,217	4,671	4,569	4,384	4,547	4,256	4,262	4,267
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA
Waste	673	161	140	119	122	133	134	134
SO_2	**20,936**	**17,189**	**15,917**	**14,829**	**14,452**	**13,928**	**14,208**	**13,910**
Stationary Fossil Fuel Combustion	18,407	15,191	13,915	12,848	12,461	11,946	12,220	11,916
Mobile Fossil Fuel Combustion	793	665	704	632	624	631	637	644
Oil and Gas Activities	390	310	283	286	289	315	315	315
Waste Combustion	39	30	30	29	30	24	24	24
Industrial Processes	1,306	991	984	1,031	1,047	1,009	1,009	1,009
Solvent Use	0	1	1	1	1	1	1	1
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0	1	1	1	1	1	1	1

NA = Not Available.
Note: Totals may not sum due to independent rounding.
Source: U.S. EPA 2005, except for estimates from field burning of agricultural residues.

Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and nonutilities combined—was the largest source of U.S. greenhouse gas emissions in 2004; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

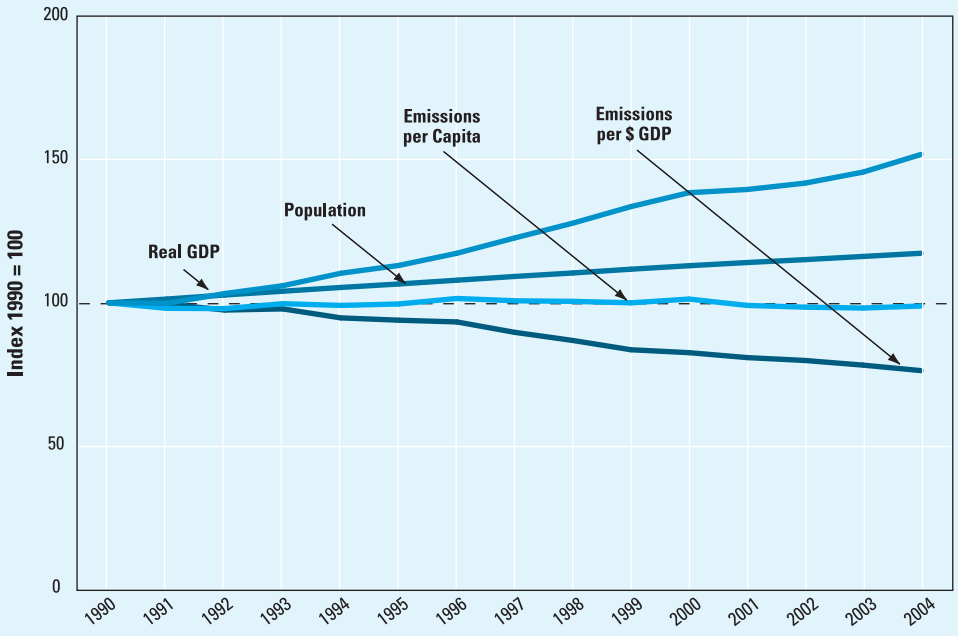
Table 3-11 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. U.S. greenhouse gas emissions have grown at an average annual rate of 1.1 percent since 1990. This rate is slower than that for total energy or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have also grown more slowly than national population since 1990 (Figure 3-15). Overall, global atmospheric CO2 concentrations a function of many complex anthropogenic and natural processes worldwide are increasing at 0.4 percent per year.

TABLE 3-11 AND FIGURE 3-15 Recent Trends in Various U.S. Data (Index 1990 = 100) and Global Atmospheric CO_2 Concentrations

Since 1990, U.S. greenhouse gas emissions have grown at an average annual rate of 1.1 percent—a rate slower than the growth in energy consumption or overall gross domestic product.

Variable	1991	1998	1999	2000	2001	2002	2003	2004	Growth Rate[f]
GDP Growth[a]	100	127	133	138	139	141	145	151	3.0%
Electricity Consumption[b]	102	121	123	127	125	128	129	131	2.0%
Energy Consumption[b]	100	112	114	117	114	116	116	118	1.2%
Fossil Fuel Consumption[b]	99	113	114	117	115	116	117	118	1.2%
Greenhouse Gas Emissions[c]	99	111	112	114	113	113	114	116	1.1%
Population Growth[d]	101	110	112	113	114	115	116	117	1.1%
Atmospheric CO_2 Concentrations[e]	100	103	104	104	105	105	106	106	0.4%

[a] Gross domestic product in chained 2000 dollars (U.S. DOC/BEA 2006a).
[b] Energy content weighted values (U.S. DOE/EIA 2004a).
[c] GWP weighted values.
[d] U.S. DOC/Census 2005.
[e] Hofmann 2004.
[f] Average annual growth rate.



4 Policies and Measures

In February 2002, President Bush set a national goal to reduce the greenhouse gas (GHG) intensity[1] of the American economy by 18 percent by 2012.[2] Meeting this commitment will prevent the release of more than 1,833 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.) to the atmosphere, adding to the 255 Tg CO_2 Eq. avoided in 2002. To help achieve this goal, President Bush has taken the following actions:

- created an interagency, cabinet-level committee to coordinate and prioritize federal research on global climate science and advanced energy technologies;
- increased the federal budget for climate change activities; and
- proposed tax incentives that help spur GHG reductions by spurring cleaner, renewable energy and more energy-efficient technologies.

The Administration is pursuing a broad range of policy measures, financial incentives, voluntary programs, and other federal programs that can help to slow the growth in GHG emissions and reduce GHG intensity. The Administration's approach balances near-term opportunities with long-term investments in breakthrough technologies needed for greater emission reductions in the future. These federal efforts span the major sectors of the U.S. economy encompassing generation and use of energy in the commercial, residential, industrial, and transportation sectors; management of agriculture and forestry; and management of waste streams and industrial byproducts. In addition, businesses, state and local governments, and nongovernmental organizations (NGOs) are addressing global climate change in numerous ways.

NATIONAL POLICYMAKING PROCESS

In 2001, the President created the National Climate Change Technology Initiative (NCCTI), charging the Secretaries of Commerce and Energy, working with other federal agencies, to:

- evaluate the state of U.S. climate change technology research and development (R&D) and make recommendations for improvement;
- provide guidance on strengthening basic research at universities and national laboratories, including the development of advanced mitigation technologies that offer the greatest promise for low-cost reductions of GHG emissions;
- develop opportunities to enhance private–public partnerships in applied R&D to expedite innovative and cost-effective approaches to reducing GHG emissions;
- make recommendations for funding demonstration projects for cutting-edge technologies; and

[1] Defined as the amount of CO_2 equivalents emitted per unit of gross domestic product (GDP).

[2] The national commitment to improve U.S. GHG intensity by 18 percent by 2012 is based on projections of U.S. GHG emissions and GDP as estimated in 2002. The commitment is to improve GHG intensity by 4 percentage points over a *Business As Usual* case, which is expected to avoid GHG emissions of about 100 million metric tons of carbon equivalents (MMTCE) (367 Tg CO_2 Eq.) in 2012 and 500 MMTCE (1,833 Tg CO_2 Eq.) cumulatively by 2012.

- evaluate improved technologies for measuring and monitoring gross and net terrestrial GHG emissions.

In February 2002, the President reorganized federal oversight, management, and administrative control of climate change activities. He established the cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI), thereby directly engaging the heads of all relevant departments and agencies in guiding and directing climate change activities, and charged the CCCSTI with developing innovative approaches in accord with a number of basic principles:

- Be consistent with the long-term goal of stabilizing GHG concentrations in the atmosphere.
- Be measured, and continually build on new scientific data.
- Be flexible to adjust to new information and take advantage of new technology.
- Ensure continued economic growth and prosperity.
- Pursue market-based incentives and spur technological innovation.
- Base efforts on global participation, including developing countries.[3]

The CCCSTI makes recommendations to the President on matters concerning climate change science and technology plans, investment, and progress. Under the auspices of the CCCSTI, two multi-agency programs were established to coordinate federal activities in this area: the U.S. Climate Change Science Program (CCSP),[4] led by the U.S. Department of Commerce (DOC), and the U.S. Climate Change Technology Program (CCTP), led by the U.S. Department of Energy (DOE). CCSP and CCTP are discussed in greater detail in Chapter 8.

The U.S global climate change strategy and the progress being made are routinely reviewed by the relevant committees and working groups. This fourth national communication demonstrates U.S. progress toward implementing the provisions of the United Nations Framework Convention on Climate Change in accordance with current knowledge of the science and U.S. efforts to develop longer-term solutions.

Federal Policies and Measures

Federal policies and measures play a central role in achieving the President's GHG intensity goal and longer-term climate change objectives. Policies consist of a balanced mix of near- and long-term, voluntary and regulatory,[5] research and development, CO_2 and other potent GHGs, and commercial, residential, industrial, and transportation sector initiatives. Federal programs and initiatives provide a comprehensive approach for the near term, and a foundation for climate science and technologies that will reduce uncertainties and deliver even greater emission reductions in the future. The United States will continue to pursue lowering GHG intensity in parallel with reducing the uncertainties in climate science and technology. The domestic policies and programs promoted by the President allow consumers and businesses to make flexible decisions about emission reductions, rather than only mandating particular control options or rigid targets. The President's policies challenge and provide incentives to businesses to reduce their GHG emissions by joining federal partnership programs promoting improved energy efficiency and increased use of renewable energy technologies. Going forward, future initiatives will build on these successes.

With sustained efforts, emission reductions accompanied by economic growth are expected to achieve the President's goal. Established programs have demonstrated the accomplishments that well-designed policies can achieve. However, the program projections in this chapter should not be compared to the information presented in Chapter 5 and should not be used directly to calculate the national projections.[6] In addition, several programs are not included in the Chapter 5 projections for a number of reasons, including double counting of benefits and stage of implementation. However, these unscored programs are still expected to contribute to the overall emission reductions and reaching the 2012 target. Representative federal domestic climate programs and their estimated GHG reduction goals are listed in Table 4-2 at the end of this chapter.

NEW INITIATIVES SINCE THE 2002 CAR

Since the last *Climate Action Report* (CAR) was published in 2002, new initiatives have been introduced to augment existing climate change activities at the federal level. They target additional sources of emissions and provide opportunities for significant reductions. Some examples of these new initiatives follow.

Climate VISION

Climate VISION[7] assists industry efforts to accelerate the transition to practices, improved processes, and energy technologies that are cost-effective, cleaner, more efficient, and more capable of reducing, capturing, or sequestering GHGs. Already, business associations representing 14 industry sectors and The Business Roundtable have become program partners with the federal government and have issued letters of intent to meet specific targets for reducing GHG emissions intensity. These partners represent a broad range of industry sectors: oil and gas production, transportation, and refining; electricity generation; coal and mineral production and mining; manufacturing; railroads; and forestry products. Partnering sectors account for about 40–45 percent of total U.S. emissions.

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[3] See <http://www.climatetechnology.gov/vision2005/cctp-vision2005.pdf>.

[4] See <http://www.climatescience.gov/>.

[5] For example, the Landfill Rule and the Significant New Alternatives Program, discussed later in this chapter.

[6] The reported impacts of individual policies and measures in this chapter are based on specific assumptions of the impacts and adoption of each measure, but recognize fewer interactions and competitive effects within and between economic sectors than the aggregate estimates used in Chapter 5. For a more detailed explanation, see Chapter 5.

[7] See <http://www.climatevision.gov/>, <http://www.pi.energy.gov/enhancingGHGregistry/>, and <http://www.eia.doe.gov/oiaf/1605/aboutcurrent.html>.

Revised Guidelines for Voluntary GHG Emissions Reporting

Revised Guidelines for Voluntary Greenhouse Gas Emissions Reporting under section 1605(b) of the Energy Policy Act of 1992 are intended to encourage utilities, industries, farmers, landowners, and other participants to submit to an on-line registry comprehensive reports on their emissions and emission reductions, including sequestration. The enhanced registry is intended to boost measurement accuracy, reliability, and verifiability, working with and taking into account emerging domestic and international approaches. For the most recent reporting year (2004), 226 U.S. companies and other organizations filed GHG reports.

Climate Leaders

Climate Leaders[8] was launched in early 2002 to encourage individual companies to develop long-term, comprehensive climate change strategies. Under this program, partners set corporate-wide GHG reduction goals and inventory their emissions to measure progress. The partnership now includes more than 100 partners, half of whom have already set GHG emission reduction goals. The U.S. GHG emissions of these partners are equal to nearly 10 percent of the U.S. total.

Green Power Partnership

As part of the U.S. Environmental Protection Agency's (EPA's) Clean Energy Initiative, the Green Power Partnership[9] assists organizations in demonstrating environmental leadership by choosing electricity products generated from renewable energy sources. The partnership now has more than 600 partners committed to purchasing more than 4 million megawatt-hours (MWh) of green power (U.S. EPA/OAR 2006).

SmartWay Transport Partnership

SmartWay Transport Partnership[10] works to increase U.S. energy efficiency and energy security, while significantly reducing air pollution and GHGs. It creates strong market-based incentives for corporations and the maritime, trucking, and rail companies that deliver their products to improve the environmental performance of freight operations.

New ENERGY STAR Products

The ENERGY STAR[11] program has expanded substantially to include new products and building types, such as schools, grocery stores, hotels, hospitals and medical office buildings, and warehouses. A national campaign challenges building owners and managers to improve energy efficiency by 10 percent or more. New ENERGY STAR-labeled products for homes and businesses have been introduced into the marketplace, including external power supplies, battery chargers, and vending machines. To date, consumers have purchased 2 billion ENERGY STAR-qualified products.

Clean Energy–Environment State Partnership Program

The Clean Energy–Environment State Partnership Program[12] encourages states to develop and implement cost-effective clean energy and environmental strategies that help further both environmental and clean energy goals and achieve public health and economic benefits.

Mobile Air Conditioning Climate Protection Partnership

Launched in 2004, the Mobile Air Conditioning Climate Protection Partnership[13] strives to reduce GHG emissions from vehicle air conditioning systems through voluntary approaches. The program promotes cost-effective designs and improved service procedures that minimize emissions from mobile air conditioning systems.

Energy Policy Act of 2005

In August 2005, President Bush signed into law the Energy Policy Act of 2005 (EPAct), a bill with far-reaching impacts on the U.S. energy economy. In addition to R&D programs, EPAct has a number of provisions designed to accelerate market penetration of advanced, clean-energy technologies. The provisions include tax breaks for production from advanced nuclear power; clean coal facilities; integrated gasification-combined cycle; energy-efficient commercial buildings, homes, and appliances (i.e., ENERGY STAR); residential energy-efficient property; business installation of fuel cells and stationary microturbine power plants; business solar investment tax credit; alternative motor vehicle credit; and nuclear power.

EPAct authorizes DOE to enter into loan guarantees for a variety of early commercial projects that use advanced technologies that avoid, reduce, or sequester air pollutants or anthropogenic sources of GHGs, and have a reasonable prospect of the borrower's repayment of the principal and interest on the obligation.[14] Eligible projects include renewable energy systems; advanced fossil fuel technology; hydrogen fuel cell technology; advanced nuclear energy facilities; carbon capture and sequestration practices and technology; efficient end-use energy technologies; efficient energy generation, transmission, and distribution; production facilities for fuel-efficient vehicles; pollution control equipment; and refineries. EPAct also provides standby default coverage for certain regulatory and litigation delays for the first six nuclear power plants. Under this provision, DOE is authorized to indemnify certain covered costs up to $500 million for each of the first two and $250 million for each of the next four nuclear power plants if full power operation is delayed because of an unmet regulatory schedule or the initiation of litigation. The provision also offers production tax credits for 6,000 megawatts of new nuclear capacity.

In addition, EPAct mandates an increase in the renewable content of gasoline from 4 billion gallons (15.1 billion liters) in 2006 to 7.5 billion gallons (28.4 billion liters) in 2012, establishes 16 new efficiency mandates covering a variety of

[8] See <http://www.epa.gov/climateleaders/>.
[9] See <http://www.epa.gov/greenpower/>.
[10] See <http://www.epa.gov/otaq/smartway/index.htm>.
[11] See <http://www.energystar.gov/>.
[12] See <http://www.epa.gov/cleanenergy/stateandlocal/partnership.htm>.
[13] See <http://www.epa.gov/cppd/mac/>.
[14] See Title XVII of the Energy Policy Act of 2005.

appliances, and requires federal agencies to improve the efficiency of their buildings. EPAct also provides for U.S. agencies to undertake a range of cooperative activities designed to reduce the greenhouse gas intensity of large developing country economies.

NEAR-TERM MEASURES

The programs discussed in this section are representative of the U.S. government's efforts to curb the growth of GHG emissions. The near-term measures in this *Climate Action Report* are defined by their implementing federal agencies as measures contributing directly to the achievement of the President's 2012 GHG intensity goal. Estimates of mitigation impacts of programs are provided by the agency responsible for each individual program, based on the agency's experience and assumptions related to the implementation of voluntary programs. These estimates may include assumptions about the continued or increased participation of partners, development and deployment goals, and/or whether the necessary commercialization or significant market penetration is achieved. Estimates of mitigation impacts for individual policies or measures should not be aggregated to the sectoral level, due to possible synergies and interactions among policies and measures that might result in double counting.

Energy: Residential and Commercial Sectors

Representing approximately 35 percent of U.S. GHG emissions, the residential and commercial sectors[15] remain an important focus of U.S. climate change policies and measures. The use of electricity for such services as lighting, heating, cooling, and running electronic equipment and appliances accounts for the majority of CO_2 emissions in these sectors. These sectors continue to have potential for significant reductions that can be realized through both regulatory and voluntary programs that set standards, provide information, develop measurement tools, and build partnerships. By using commercially available, energy-efficient products, technologies, and best practices, many commercial buildings and homes could save up to 30 percent on energy bills and substantially reduce GHG emissions. Following are descriptions of key policies and measures aimed at saving energy and avoiding GHG emissions in the residential and commercial sectors.

ENERGY STAR for the Commercial Market

The ENERGY STAR program has expanded in the commercial market, as it continues to offer thousands of organizations a strategy for superior energy management and standardized tools for measuring their energy efficiency. Since 2002, the U.S. Environmental Protection Agency (EPA) has expanded a key effort first introduced in 1999—a national energy performance rating system that allows interested parties to rate the energy efficiency of a building on a scale from zero to 100 and to recognize top-performing ENERGY STAR buildings. This system has been valuable in identifying cost-effective opportunities for improvements for a wide range of building types, including hospitals, schools, grocery stores, office buildings, warehouses, and hotels.

The ENERGY STAR program is helping the commercial marketplace respond to the President's challenge to business to voluntarily take actions that reduce GHG emissions. In 2005, EPA joined more than 20 trade associations, businesses, and state-based institutions to challenge businesses and institutions across the country to take the necessary steps to identify the many buildings where financially attractive improvements can reduce energy use by 10 percent or more, and to make the improvements. EPA has also announced it will recognize organizations, businesses, and institutions demonstrating energy savings across their building portfolios by 10, 20, or 30 points, as ENERGY STAR Leaders. EPA estimates that in 2002, ENERGY STAR in the commercial building market helped businesses reduce GHG emissions by 35 Tg CO_2 Eq. and save $3 billion in energy costs. EPA projects that pursuing this effort could result in reductions of 64 Tg CO_2 Eq. in 2012.

Commercial Building Integration

The Commercial Building Integration[16] (CBI) program works to realize energy-saving opportunities provided by advancing a whole-building approach for commercial construction and major renovation. CBI is increasing its industry partnerships in design, construction, operation and maintenance, indoor environment, and control and diagnostics of heating, ventilation, air conditioning, lighting, and other building systems. Through these efforts, DOE helps transfer the most energy-efficient building techniques and practices into commercial buildings through regulatory activities, such as supporting the upgrade of voluntary (model) building energy codes and promulgating upgraded federal commercial building energy codes.

Since 2002, CBI has facilitated a 10 percent increase in commercial building designs that incorporate energy efficiency design tools. In 2005, the program assessed control technologies, optimization methods, and market opportunities to establish a framework for developing programmatic pathways to improve energy efficiency in buildings by 50 percent or better, enabling the development of energy-efficient design and technology packages for new commercial buildings. DOE estimates that CBI, in conjunction with Rebuild America, could reduce GHG emissions by 0.5 Tg CO_2 Eq. in 2012.

Rebuild America

Rebuild America[17] is being redesigned to be better integrated with DOE's Commercial Building Integration program, described above. This program works with a network of hundreds of community-based partnerships across the Nation that

[15] See <http://www.eere.energy.gov/buildings/>.
[16] See <http://www.eere.energy.gov/buildings/high performance/>.
[17] See <http://www.eere.energy.gov/buildings/program_areas/rebuild.html>.

are saving energy, improving building performance, decreasing air pollution through reduced energy demand, and enhancing the quality of life through energy efficiency and renewable energy technologies. In 2005, the program helped Rebuild America community partnerships to upgrade 5.6 million square meters (60 million square feet) of floor space in K-12 schools, colleges, public housing, and state and local governments, reducing the average energy used in these buildings by 18 percent.

Residential Building Integration: Building America

The objective of Building America[18] is to design, build, and evaluate energy-efficient homes that use 30–40 percent less total energy than comparable traditional homes with little or no increase in construction costs, and for industry to adopt these practices for new home construction. The program optimizes building energy performance and savings through the integration of new technologies with innovative residential building practices. Ongoing research also focuses on integrating on-site power systems, including renewable energy technologies.

The Building America approach has built more than 32,000 homes in 36 states. Through the program, DOE and its more than 470 industry partners are conducting research to develop advanced building energy systems to make homes and communities much more energy-efficient. The energy technologies and solutions being advanced by the program will contribute to a 70 percent reduction in energy use of new prototype residential buildings that, when combined with on-site energy technologies, will result in "zero-energy homes" by 2020 and a 20 percent reduction in energy use of existing homes. DOE estimates these efforts could generate 3.8 Tg CO_2 Eq. of emission reductions in 2012.

ENERGY STAR for the Residential Market

The ENERGY STAR programs in the residential sector have been expanded since 2002. In addition to ongoing efforts in the new construction marketplace, this program is developing several program models for the existing homes stock that focus on energy efficiency opportunities with the home envelope (e.g., windows) and heating and cooling systems. With new construction, close to 10 percent of the new homes were built to ENERGY STAR specifications in 2005, meaning they were 30 percent more efficient than model energy code (or 15 percent more efficient than state energy code, whichever is stricter).

In the existing homes market, ENERGY STAR has expanded to a whole-house retrofit program, Home Performance with ENERGY STAR. Trained and certified contractors conduct whole-house energy audits and implement the requisite cost-effective efficiency improvements, backed by a strong quality assurance program. EPA estimates that homeowners could save 20–30 percent on their total energy bills under this program.

ENERGY STAR has also expanded into the affordable housing market in partnership with the U.S. Department of Housing and Urban Development. EPA estimates that these programs may provide about 7 Tg CO_2 Eq. in emission reductions in 2012.

Residential Appliance Standards

This DOE-managed program develops, promulgates, and enforces test procedures and energy conservation standards for residential appliances and certain commercial equipment. Federal residential energy efficiency standards[19] that have been in effect since 1988 or that will take effect by the end of 2007 could save an estimated total of 34 quadrillion Btus of energy by 2020. In 2012 alone, DOE estimates a reduction of 5 Tg CO_2 Eq.

Emerging Buildings Technologies[20]

This DOE program develops cost-effective, energy-efficient, advanced technologies for residential and commercial buildings, including lighting, building envelope, and space heating and cooling technologies. Technologies developed by this program could penetrate the market and avoid an estimated 4.4 Tg CO_2 Eq. in 2012 and 25.4 Tg CO_2 Eq. in 2020.

ENERGY STAR-Labeled Products

ENERGY STAR continues to grow in its coverage of efficient products for the home and business and partnerships with major retailers, energy utilities, states, and others. The label is now available on models in more than 40 product categories. Awareness of the ENERGY STAR label has grown to more than 60 percent, and many consumers report using the ENERGY STAR label as part of their purchasing decisions. The program is currently focused on maintaining the integrity of the ENERGY STAR brand, identifying new product categories for ENERGY STAR, as well as increasing the stringency of performance requirements for existing product categories, where appropriate. About 2 billion ENERGY STAR-qualified products were purchased through 2005. Due to the increased penetration of these products, EPA estimates that 39 Tg CO_2 Eq. of emissions were avoided in 2002 and projects that 102 Tg CO_2 Eq. may be avoided in 2012.

Weatherization Assistance Program

During the last 30 years, DOE's Weatherization Assistance Program[21] has provided cost-effective energy efficiency improvements to more than 5.5 million low-income households through the weatherization of homes. The program gives priority to the elderly, people with disabilities, families with children, and households that spend a disproportionate amount of their income on energy bills. (Low-income families spend 15–20 percent of household expenses on utility bills, compared to 5 percent or less for all other Americans.) On average, DOE estimates that weatherization reduces heating bills by 31 percent and overall energy bills by $358 per year at current prices,

[18] See <http://www.eere.energy.gov/buildings/building_america/>.
[19] See <http://www.eere.energy.gov/buildings/appliance_standards/>.
[20] See <http://www.eere.energy.gov/buildings/tech/emerging.html>.
[21] See <http://www.eere.energy.gov/weatherization/>.

thereby assisting low-income families in meeting their energy needs, while also reducing GHG emissions. DOE estimates that the homes being weatherized through this program could displace 4 Tg CO_2 Eq. in 2012.

Additional Policies and Measures

State Energy Program[22]—This federal program strengthens and supports the capabilities of states to promote energy efficiency and to adopt renewable energy technologies. DOE estimates that this program will displace 3 Tg CO_2 Eq. in 2012.

Energy: Industrial Sector

At about 30 percent, the industrial sector has the greatest GHG emissions, largely from fossil fuel combustion on site or at the power generation source. The numerous energy-intensive U.S. industries provide ample opportunities for efficiency improvements and emission reductions. Policies and measures included in this section target the industrial sector by promoting cost-effective investments in technologies and practices to improve industrial productivity, lower energy costs, and reduce waste.

ENERGY STAR for Industry

The ENERGY STAR program also works with manufacturing industries to enable them to enhance their corporate energy management systems. EPA is working with specific industries to identify barriers to energy performance, define strategies for minimizing these barriers, and design management tools that will assist the industries with improvements. These efforts include the development of plant energy performance indicators that enable the industries to assess the efficiency of particular manufacturing plants, building upon the successful energy performance and benchmarking work in the commercial sector.

Since 2002, the program has worked with hundreds of industrial companies across energy-intensive and nonintensive sectors, including the automobile manufacturing, cement, corn refining, food processing, glass, petroleum, pharmaceutical, and water and wastewater industries. ENERGY STAR has provided strategies and guidance to help these businesses voluntarily improve the energy efficiency of their operations, and at the same time contribute to the President's overall GHG intensity improvement goal. EPA estimates that in 2002, ENERGY STAR in the industrial sector prevented 14 Tg CO_2 Eq. and could avoid 21 Tg CO_2 Eq. in 2012.

Industrial Technologies Program

ITP: Research and Development—The Industrial Technologies Program[23] (ITP) works in partnership with the Nation's industrial sector to improve its energy intensity, enhance its long-term competitiveness, and accelerate research, development, and commercialization of technologies that increase energy and resource efficiency. ITP develops, manages, and implements a balanced portfolio of technology investments to address industry requirements throughout the technology development cycle. R&D—particularly high-risk, high-return R&D—is conducted to target efficiency opportunities in manufacturing processes and crosscutting energy systems. Validation and verification of technology benefits through intermediate-term pilot and demonstration phases help emerging technologies gain commercialization and near-term adoption.

ITP has contributed to the development of hundreds of commercialized industrial technologies, perhaps accelerating energy savings that might not have happened without DOE assistance. DOE estimates this program could reduce approximately 18 Tg CO_2 Eq. in 2012.

ITP: Best Practices and Save Energy Now—This program works with industry to identify plant-wide opportunities for energy savings and process efficiency. By implementing new technologies and system improvements, many companies are realizing the benefits of applying a Best Practices[24] approach. In 2006, the program introduced a new campaign called Save Energy Now[25] to address high U.S. natural gas prices. Also in 2006, DOE continued energy savings assessments of 200 energy-intensive facilities, and will offer an additional 250 assessments in 2007. The facilities received a targeted, three-day steam- or process-heating assessment by a DOE energy efficiency expert using the DOE software analysis tools. The 200 assessments identified $475 million per year in potential energy cost savings, that could reduce natural gas consumption by more than 50 trillion Btus per year, equivalent to the natural gas consumed by more than 725,000 typical homes. The annual carbon reduction from these energy savings is estimated at 17 Tg CO_2 Eq.

ITP: Industrial Assessment Centers[26]—These centers provide eligible small- and medium-sized manufacturers no-cost energy assessments, serve as a training ground for engineers who conduct energy audits or industrial assessments, and provide recommendations to manufacturers to help them identify opportunities to improve productivity, reduce waste, and save energy. The continuing efforts of this program may reduce an estimated 18 Tg CO_2 Eq. in 2012.

ITP: Process Technologies[27]— This activity addresses the critical technology challenges partners face for developing materials and production processes. An example is the isothermal melting (ITM) technology, which reduces energy use by 50 percent and emissions by 80 percent. The first ITM has been installed at the Aleris International Rolled Products plant in Uhrichsville, Ohio. This technology could save the U.S. aluminum industry 18 trillion Btus per year and reduce carbon emissions by 1 Tg CO_2 Eq. per year by 2020.

ITP: Crosscutting Technologies[28]—This activity addresses technologies that affect all

[22] See <http://www.eere.energy.gov/state_energy_program/>.
[23] See <http://www.eere.energy.gov/industry/bestpractices/>.
[24] See < http://www.eere.energy.gov/industry/
[25] See <http://www.eere.energy.gov/industry/bestpractices/index.html>.
[26] See <http://www.eere.energy.gov/industry/program_areas/industries.html>.
[27] See <http://www.eere.energy.gov/industry/bestpractices/iacs.html>.
[28] See < http://www.eere.energy.gov/industry/program_areas/crosscutting_technologies.html>.

manufacturing sector energy systems. An example is the Super Boiler technology, which can achieve 94 percent boiler steam efficiency with NO_x emissions below 5 parts per million volume. DOE estiamtes this technology could save the U.S. industry 180 trillion Btus per year and reduce carbon emissions by an estimated 10 Tg CO_2 Eq. per year by 2020.

Energy: Supply

Electricity generation from fossil fuels is a major contributor to U.S. CO_2 emissions. Federal policies and measures aimed at energy supply promote CO_2 reductions through the development of more energy-efficient technologies for power generation and transmission, cleaner fuels, and the use of more nuclear power and renewable resources. Solar energy, wind power, biopower, and hydrogen are some of the renewable resources supported by the United States. Tax credits have helped increase domestic investments in renewable energy and continue to accelerate the cost-competitiveness of these emerging technologies.

Nuclear Energy Plant Optimization Program

The Nuclear Energy Plant Optimization Program supports the use of nuclear energy in the United States by conducting research and development focused on improving the operations and reliability of currently operating nuclear power plants, while maintaining a high level of safety and security. The program made significant progress toward addressing many of the aging material and generation optimization issues, which have been identified as the key long-term issues facing current operating plants. This program has helped extend the life of the existing fleet of nuclear power plants without compromising safety, thus reducing the need for additional fossil fuel-fired generation capacity.

Nuclear Power 2010 Program

Nuclear Power 2010,[29] funded at $66 million in fiscal year 2006, supports deployment of new U.S. nuclear power plants. Activities include completing the cost-shared Early Site Permit demonstration projects, with issuance of three Early Site Permits at three utility sites by the U.S. Nuclear Regulatory Commission (NRC). In addition, the program supports the development of advanced nuclear plant technologies, evaluates the business case for building new nuclear power plants, and demonstrates the NRC's new Construction and Operating License process.

Renewable Energy Commercialization

Wind Energy[30]—Wind energy is the world's fastest-growing energy-supply technology. Today, the United States has more than 10,000 MW of wind-generating capacity. DOE's wind program has successfully graduated its high-speed wind effort, meeting its cost-of-energy goal of 3 cents/kilowatt-hour (kWh) in Class 6 winds in 2004. Electricity generated from wind power in America displaced approximately 11,000 short tons of CO_2 emissions in 2004. (Note that this figure assumes that wind displaces new coal generation.) Since 2002, the program has focused most of its efforts on low-wind-speed technologies and, through its public–private partnerships, has improved the cost of energy for large systems in Class 4 onshore winds from 5.5 cents/kWh in 2002 to 4.3 cents/kWh in 2005. Based on the recent emergence of U.S. offshore wind power development prospects and assessments of potential national benefits, the program is also supporting activities addressing barriers and opportunities for this U.S. energy market segment. DOE estimates that realizing the program's R&D goals could result in wind energy displacing 5 Tg CO_2 Eq. in 2012.

Solar Energy[31]—This program is improving the performance of solar energy systems and reducing development, production, and installation costs to competitive levels, thereby accelerating large-scale usage across the Nation. When federal solar energy research began in the 1970s, the cost of electricity from solar resources was about $2.00/kWh. Technological advances over the last two decades have significantly reduced solar electricity costs. Today, the cost of solar electricity ranges from as low as $0.12/kWh for concentrating solar power to $0.18/kWh for certain photovoltaic applications. DOE estimates that realizing the program's R&D goals could result in solar energy displacing 0.2 Tg CO_2 Eq. in 2012.

Geothermal Energy[32]—This program works in partnership with industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. Geothermal energy production generates electricity or provides heat for direct applications, including aquaculture, crop drying, and district heating, or for use in heat pumps to heat and cool buildings. The technologies developed by this program will provide the Nation with new sources of electricity that are highly reliable and cost-competitive and do not add to America's air pollution or GHG emissions. In 2004, U.S. electricity generated from geothermal power displaced about 11,000 short tons of CO_2 emissions.

Biofuels[33]—DOE has contributed to the advancement of biomass technology by testing and demonstrating biomass co-firing with coal, developing advanced technologies for biomass gasification, developing and demonstrating small modular systems, and developing and testing high-yield, low-cost biomass feedstocks. This research has helped biomass become a proven commercial electricity-generation option in the United States. With about 9,700 MW of installed capacity in 2004 (wood and waste), it is estimated that biomass displaced approximately 50,000 tons of CO_2 emissions in 2004.

Distributed Energy

The Distributed Energy Program[34] supports cost-effective R&D aimed at lowering costs, reducing emissions, and improving reliability and performance to

[29] See <http://np2010.ne.doe.gov/> and <http://www.ne.doe.gov/infosheets/np2010.pdf>.
[30] See <http://www.eere.energy.gov/windandhydro/wind_research.html>.
[31] See <http://www.energy.gov/energysources/solar.htm>.
[32] See <http://www.eere.energy.gov/geothermal/>.
[33] See <http://www.eere.energy.gov/biomass/>.
[34] See <http://www.eere.energy.gov/de/>.

expand opportunities for the current and future installation of distributed energy equipment. The program is working to develop and commercialize by 2015 a diverse array of high-efficiency, integrated, distributed-generation, and thermal-energy technologies at market-competitive prices, so that homes, businesses, industry, communities, and electricity companies choose to use them. Along with reducing GHG emissions, these technologies will increase the reliability of America's electricity system. DOE anticipates that the efforts of this program could avoid almost 24 Tg CO_2 Eq. in 2012.

Clean Energy Initiative

EPA's Clean Energy Initiative consists of two partnership programs that promote cost-effective technologies that offer improved efficiencies and lower emissions than traditional energy supply options. EPA projects the continued efforts of these two programs will spur new clean energy investments that could avoid 29 Tg CO_2 Eq. of GHG emissions in 2012.

Green Power Partnership[35]—This program facilitates the purchase of environmentally friendly electricity from renewable energy sources by addressing the market barriers that stifle demand. Since its launch in 2001, the Green Power Partnership has grown to more than 600 partners who have committed to purchasing 4 billion kWh of green power.

Combined Heat and Power (CHP) Partnership[36]—Also launched in 2001, CHP provides technical assistance to organizations across multiple sectors that invested in CHP projects and assisted state governments in designing regulations that encourage investment in CHP. As a result, the program now includes 170 partners who have installed 3,460 MW of operational CHP.

Carbon Sequestration Program

DOE's Carbon Sequestration Program[37] will focus primarily on developing capture and separation technologies that dramatically lower the costs and energy requirements of reducing CO_2 emissions from fossil fuel process treatment. The program's goal is to research and develop a portfolio of safe, cost-effective GHG capture, storage, and mitigation technologies by 2012, leading to substantial market penetration beyond 2012. DOE estimates the impacts of resultant technologies to be 30.3 Tg CO_2 Eq. in 2012 and 34.0 Tg CO_2 Eq. in 2020.

Additional Policies and Measures

Woody Biomass—The Secretaries of Agriculture, Energy, and the Interior signed an agreement in June 2003 to encourage the use of woody biomass from forest, rangeland, and woodland land management treatments wherever ecologically sustainable. Such use can reduce smoke and GHG emissions by up to 97 percent, compared to open burning. Use of woody biomass as a bio-based product (timber, engineered lumber, paper and pulp, furniture, plastics, etc.) may also sequester carbon by an unspecified amount.

In May 2005, the Department of the Interior (DOI) issued a regulation authorizing the removal and use of woody biomass from all land management projects, wherever ecologically appropriate and in accordance with the law, from the 500 million acres managed by DOI.

Transportation

Corporate Average Fuel Economy Program

The Corporate Average Fuel Economy[38] (CAFE) program requires automobile manufacturers to meet average fuel economy standards for the light-duty vehicle fleet sold in the United States. The passenger car standard has been set by statute at 11.7 kilometers per liter(kpl) (27.5 miles per gallon (mpg)), but can be amended through rulemaking. In 2003, the National Highway Traffic Safety Administration (NHTSA) raised the standard for minivans, pickup trucks, sport utility vehicles (SUVs), and other light trucks from 8.8 kpl (20.7 mpg) to 8.9 kpl (21.0 mpg) for 2005, 9.2 kpl (21.6 mpg) for 2006, and 9.4 kpl (22.2 mpg) for 2007. The action more than doubles the increase in the standard that occurred between 1986 and 2001, a period of more than 15 years. It is predicted that this activity might save approximately 412 trillion Btus (3.6 billion gallons) of gasoline over the life of model year 2005–07 light-truck fleets and is projected to result in emission reductions of 42 Tg of CO_2 Eq. in 2012 for all light trucks after model year 2005.

In March 2006, NHTSA issued a new rule for light trucks covering model years 2008–11. The new rule raises required light-truck fuel economy to 24 mpg by model year 2011 and will save nearly 1,259 trillion Btus (11 billion gallons) of gasoline (73 Tg of CO_2 Eq.) over the life of the affected vehicles. The new rule includes an innovative reform that varies fuel economy standards according to the size of the vehicle. The regulation has also been extended for the first time to large passenger vans and SUVs.

SmartWay Transport Partnership

This voluntary partnership[39] between EPA and the transportation industry aims to increase energy efficiency while significantly reducing GHGs and air pollution. EPA provides tools and models to help SmartWay Transport partners adopt cost-effective strategies to save fuel and reduce emissions.

To date, more than 500 companies and organizations have joined the partnership. Freight shippers meet their goals by using participating carriers, while trucking and rail companies meet their goals by improving freight transport efficiency.

The SmartWay National Transportation Idle Free Corridor Program has established 86 projects to reduce long-duration truck and locomotive idling, converting more than 5,000 parking spaces to no-idle zones. To help states improve idle-reduction policies and programs, EPA published a model idle-reduction law.

[35] See <http://www.epa.gov/greenpower/index.htm>.
[36] See <http://www.epa.gov/chp/index.htm>.
[37] See <http://www.fe.doe.gov/programs/sequestration/index.html>.
[38] See <http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.d0b5a45b55bfbe582f57529cdba046a0/>.
[39] See <http://www.epa.gov/smartway/>.

SmartWay Upgrade Kits, available through truck dealerships and parts dealers, can save companies up to 15 percent in fuel and CO_2 emissions per year. EPA partnered with the Small Business Administration to offer SmartWay Upgrade Kit loans, and will publish guidance for states to initiate these projects.

Other SmartWay initiatives include EPA's recent announcement of a SmartWay designation for new, clean, and efficient tractor-trailer combination trucks, which can save 10–20 percent annually in fuel and CO_2 emissions. SmartWay's supply-chain initiative is developing new strategies to provide a more efficient integration of marine transport, port operations, and logistics. And to encourage the use of low-carbon renewable fuels, EPA recently introduced SmartWay Grow and Go, which aims for 25 percent of SmartWay partners to use biofuels by 2012.

EPA estimates the SmartWay Transport partnership could reduce emissions by 33 Tg CO_2 Eq. in 2012.

Renewable Fuel Standard

Under the Energy Policy Act of 2005, EPA is responsible for promulgating regulations to ensure that gasoline sold in the United States contains a specific volume of renewable fuel. This national Renewable Fuel Standard will increase the volume of renewable fuel that is blended into gasoline, starting with calendar year 2006. The standard is intended to double the amount of renewable fuel usage by 2012.

FreedomCAR and Fuel Partnership and Vehicle Technologies Program

This public–private partnership[40] with the Nation's automobile manufacturers and petroleum companies promotes the development of hydrogen as a primary fuel for cars and trucks. Its focus is on research needed to develop hydrogen from domestic renewable sources and technologies that utilize hydrogen, such as fuel cells. The program[41] works jointly with DOE's hydrogen, fuel cell, and infrastructure R&D efforts and the efforts to develop improved technology for hybrid electric vehicles. These advanced technologies —which include the hybrid electric components (such as batteries and electric motors), advanced materials to reduce the weight of vehicles, advanced high-efficiency combustion engines, and advanced fuels—could result in dramatic reductions of criteria pollutants and GHG emissions from the transportation sector.[42] DOE estimates that achieving its vehicle technology R&D goals could reduce carbon emissions by about 11.5 Tg CO_2 Eq. by 2012.

Clean Cities

The benefits of Clean Cities[43] are now included in the FreedomCAR and Fuel Partnership and in the Vehicle Technologies Program. This DOE program supports efforts to deploy alternative fuel vehicles (AFVs) and develop the necessary supporting infrastructure. Clean Cities works through a network of more than 85 volunteer, community-based coalitions to promote the use of alternative fuels and petroleum-displacement technologies, and to advance the use of alternative fuel blends, idle-reduction technologies, hybrid electric vehicles, and fuel economy practices. Clean Cities stakeholders have added approximately 200,000 AFVs to their fleets, which have displaced more than 109 trillion Btus (950 million gallons) of petroleum since 1994.

Congestion Mitigation and Air Quality Improvement Program

Administered by DOT in consultation with EPA, the Congestion Mitigation and Air Quality (CMAQ) Improvement Program,[44] provides states with funds to reduce congestion and to improve air quality through transportation control measures and other strategies. The amount of funding given to a state is based on the severity of the air quality problem and the population of the area that does not meet air quality standards. State and local governments select the projects to fund and coordinate them through metropolitan planning organizations. The projects vary by region, but typically include transit improvements, alternative fuel programs, shared-ride services, traffic flow improvements, demand management strategies, pedestrian and bicycle programs, and inspection and maintenance programs. Other activities, such as idle-reduction, diesel engine retrofits, and education and outreach programs, may also be eligible for CMAQ funds. Transportation control measures in air quality plans—strategies to reduce pollution by reducing vehicle use or improving traffic flow—receive priority funding under CMAQ. Nearly 16,000 air quality projects have received CMAQ funding since 1992, resulting in significant reductions in vehicle emissions, including GHG emissions.

Aircraft Fuel Efficiency

Aviation yields GHG emissions that have the potential to influence global climate. In the United States, aviation makes up about 3 percent of the national GHG inventory and about 12 percent of transportation emissions. Currently, measuring and tracking fuel efficiency from aircraft operations provide the data for assessing the improvements in aircraft and engine technology, operational procedures, and the airspace transportation system that reduce aviation's contribution to CO_2 emissions. DOT has a goal to improve aviation fuel efficiency per revenue plane-mile by 1 percent per year through 2009. In the near term, new technologies to improve air traffic management will help reduce fuel burn and, thus, emissions. In the long term, new engines and aircraft will feature more efficient components and aircraft aerodynamics, enhanced engine cycles, and reduced weight, thereby improving fuel efficiency.

Biomass and Biorefinery Systems Program[45]

DOE and the U.S. Department of Agriculture (USDA) partner with industry to foster R&D of advanced technologies that

[40] See <http://www.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html>.
[41] See <http://www.eere.energy.gov/vehiclesandfuels/>.
[42] The U.S. government uses six "criteria pollutants" as indicators of air quality: ozone, carbon monoxide, sulfur dioxide, nitrogen dioxides, particulate matter, and lead.
[43] See <http://www.eere.energy.gov/cleancities/>.
[44] See <http://www.fhwa.dot.gov/environment/cmaqpgs/>.
[45] See <http://www.eere.energy.gov/biomass/>.

will convert U.S. biomass resources into affordable industrial products (including energy and higher-valued chemicals and materials) through the development of biorefineries. An analogy to this approach is the petroleum refinery that refines crude oil into a broad range of industrial products. In the future, biorefineries will use advanced technology—such as hydrolysis of cellulosic biomass to sugars and lignin and thermochemical conversion of biomass to synthesis gas for fermentation and catalysis of these platform chemicals—to produce slates of biopolymers and fuels. Today, America's environment is reaping the benefits of the public–private R&D partnerships that have formed over the past two decades and that, in combination with government energy policies, have resulted in such alternative fuels as gasohol (a combination of gasoline and ethanol), accounting for approximately 10 percent of the fuel used on U.S. highways. By 2012 these efforts could yield an estimated 0.6 Tg CO_2 Eq. in avoided emissions.

Industry: Non-CO_2

Methane Programs

U.S. industries, along with state and local governments, collaborate with EPA to implement several voluntary programs that promote profitable opportunities for reducing emissions of methane, an important GHG.[46] These programs are designed to overcome a wide range of informational, technical, and institutional barriers to reducing methane emissions, while creating profitable activities for the coal, natural gas, and petroleum industries. The collective results of EPA's voluntary methane partnership programs have been substantial. Total U.S. methane emissions in 2004 were 10 percent lower than emissions in 1990, despite robust economic growth over that period. EPA projects these programs may maintain emissions below 1990 levels beyond 2012, due to expanded industry participation and the continuing commitment of the participating companies to identify and implement cost-effective technologies and practices.

Natural Gas STAR[47]—Through this partnership program, EPA works with companies that produce, process, transmit, and distribute natural gas to identify and promote the implementation of cost-effective technologies and practices to reduce methane emissions. Since its launch in 1993, Natural Gas STAR has been successful in reducing methane emissions and bringing more energy to markets. As of 2004, Natural Gas STAR partner companies represented almost 60 percent of the U.S. natural gas industry. EPA estimates the program reduced methane emissions by 20 Tg CO_2 Eq. in 2002. Because of the program's expanded reach, EPA estimates the reduction for 2012 may be 28 Tg CO_2 Eq.

Coalbed Methane Outreach Program[48]—The fraction of coal mine methane from degasification systems captured and used grew from 25 percent in 1990 to more than 70 percent in 2002. Initiated in 1994, the Coalbed Methane Outreach Program (CMOP) is working to demonstrate technologies that can eliminate the remaining emissions from degasification systems, and is addressing methane emissions in mine ventilation air. EPA estimates that CMOP reduced 6 Tg CO_2 Eq. in 2002. Due to enhanced market opportunities for natural gas and power, EPA anticipates further refinement of technical options for the capture and utilization of mine methane, a growing reliance on methane degasification in the western United States, and CMOP's continued success in reducing ventilation air methane over the next few years. EPA projects CMOP could reduce emissions by 10 Tg CO_2 Eq. in 2012.

High-GWP Programs

The United States is one of the first nations to develop and implement a national strategy to control emissions of high-GWP gases. The strategy is a combination of industry partnerships and regulatory mechanisms to minimize atmospheric releases of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—which are potent GHGs that contribute to global warming—while ensuring a safe, rapid, and cost-effective transition away from chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, and other ozone-depleting substances across multiple industry sectors.

Environmental Stewardship—The objective of this initiative is to limit emissions of HFCs, PFCs, and SF_6 in three industrial applications: semiconductor production,[49] electric power distribution,[50] and magnesium production.[51] Since 2002, the SF_6 emission reduction partnership for magnesium set a goal to eliminate emissions of SF_6 by the end of 2010. Additional sectors are being assessed for the availability of cost-effective emission reduction opportunities and are being added to this initiative.

EPA estimates that Environmental Stewardship partners reduced emissions by 5 Tg CO_2 Eq. in 2002, and projects they may reduce emissions by 35 Tg CO_2 Eq. in 2012. Because of a significant decline in the growth rates of domestic production, particularly in the magnesium and semiconductor industries, EPA's estimate of the total 2012 reduction is more than 50 percent less than had been expected in 2002. Nonetheless, significant reductions per unit of activity in these sectors are attributable to this initiative's voluntary partnerships.

HFC-23—This partnership continued to encourage companies to develop and implement technically feasible, cost-effective processing practices or technologies to reduce HFC-23 emissions from the manufacture of the ozone-depleting substance HCFC-22. Despite a 4 percent increase in production compared to 1990, EPA estimates that total emissions in 2002 were significantly below 1990 levels. Compared to the *Business As Usual* case in 2002, there was a reduction of 17 Tg CO_2 Eq. EPA

[46] See <http://www.epa.gov/methane/index.html>.
[47] See <http://www.epa.gov/gasstar/index.htm>.
[48] See <http://www.epa.gov/cmop/index.html>.
[49] See <http://www.epa.gov/semiconductor-pfc/>.
[50] See <http://www.epa.gov/highgwp/electricpower-sf6/index.html>.
[51] See <http://www.epa.gov/magnesium-sf6/>.

estimates a reduction of 16 Tg CO_2 Eq. for 2012, which is lower than EPA anticipated in 2002. One major U.S. producer stopped manufacturing HCFC-22 in 2002; thus, the reduction potential has declined due to lower total production.

Voluntary Aluminum Industry Partnership[52]—This partnership has continued to reduce CF_4 and C_2F_6 where cost-effective technologies and practices are technically feasible. Since 2002, the partnership expanded its reduction goal to reduce direct carbon emissions from anode consumption as well as PFCs. EPA estimates that the partnership reduced PFC emissions by 7 Tg CO_2 Eq. in 2002 and projects reductions of 10 Tg CO_2 Eq. in 2012.

Significant New Alternatives Program[53]—Since the 2002 CAR, the Significant New Alternatives Program (SNAP) has continued its progress in phasing down the use of ozone-depleting substances (ODSs), such as CFCs and HCFCs. SNAP has worked closely with industry to research, identify, and implement climate- and ozone-friendly alternatives, supporting a smooth transition to these new technologies. In addition, SNAP has initiated programs with different industry sectors to monitor and minimize emissions of global-warming gases, such as HFCs and PFCs used as substitutes for ozone-depleting chemicals. By limiting use of these gases in specific applications where safe alternatives are available, SNAP reduced emissions by an estimated 26 Tg CO_2 Eq. in 2002 and is projected to reduce emissions by 150 Tg CO_2 Eq. in 2012.

Mobile Air Conditioning Climate Protection Partnership[54]—Announced in 2004, the Mobile Air Conditioning Climate Protection Partnership is striving to reduce GHG emissions from vehicle air conditioning systems through voluntary approaches. The program will identify near-term opportunities to improve the environmental performance of mobile air conditioners and to promote cost-effective designs and improved service procedures that minimize emissions from mobile air conditioning systems. Partnership members are pursuing two goals: reduce fuel consumption from the operation of vehicle air conditioning by at least 30 percent, and reduce direct refrigerant emissions by 50 percent, thereby avoiding emissions of HFC-134a, a very potent GHG. Drivers will save money by using less fuel, and will benefit from improved air conditioning reliability due to improved technology. EPA estimates that this effort will avoid more than 5 Tg CO_2 Eq. in 2012.

Additional Policies and Measures

Voluntary Code of Practice for the Reduction of Emissions of HFC & PFC Fire Protection Agents—In 2002, EPA and several hundred equipment and chemical manufacturers and distributors representing the U.S. fire protection industry launched the Voluntary Code of Practice for the Reduction of Emissions of HFC & PFC Fire Protection Agents (VCOP). Successful implementation of VCOP achieves the dual goals of minimizing nonfire emissions of HFCs and PFCs, used as fire-suppression alternatives to ozone-depleting halons, and continuing to protect people and property from the threat of fire through the use of proven, effective products and systems.

Green Grocer—EPA is working with supermarket companies and equipment manufacturers to promote the deployment of new, energy-efficient technologies that reduce emissions of fluorocarbon refrigerants (including HFCs). The first stage of this program is underway and includes EPA and industry evaluations of the performance, feasibility, costs, and benefits of alternative systems in stores.

Agriculture

USDA is providing incentives and supporting voluntary actions by private landowners to conserve and protect natural resources on agricultural lands. USDA conservation programs were established to provide broad conservation goals, such as cleaner water and reduced soil erosion. Many of the actions and activities supported by these programs also reduce GHG emissions and increase carbon sequestration. To bolster these benefits, in 2003, USDA announced that, for the first time, it would give consideration to GHG benefits in implementing the Nation's forest and agriculture conservation programs. Major elements of the USDA actions to reduce GHGs are described in the following sections.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program[55] (EQIP) provides financial assistance for conservation practices on working farm and ranch lands. The Natural Resources Conservation Service (NRCS) provided guidance to its state offices that noted that conservation technologies and systems for reducing emissions, increasing carbon sequestration, and achieving other environmental benefits can be compatible with production agriculture, and encouraged recognition for these extra efforts within the local EQIP ranking systems. A wide array of conservation practices can reduce GHG emissions, including residue management, irrigation water management, nutrient management, crop rotations, cover crops, wetland restoration, and grazing land management.

For two practices, NRCS has estimated EQIP's contribution to mitigating GHG emissions. In 2005, EQIP provided assistance to farmers to adopt residue management on about 1 million hectares (ha) (2.47 million acres (ac)), which is estimated to sequester about 2 Tg CO_2 Eq. per year. In addition, reduced use of diesel fuel on these same lands could lower CO_2 emissions by as much as 0.1 Tg CO_2 Eq. per year. Also in 2005, EQIP provided assistance to ranchers to undertake prescribed grazing on 1.8 million ha (4.5 million ac), which is estimated to sequester about 0.3 Tg CO_2 Eq. per year.

[52] See <http://www.epa.gov/highgwp/aluminum-pfc/index.html>.
[53] See <http://www.epa.gov/ozone/snap/index.html>.
[54] See <http://www.epa.gov/cppd/mac/>.
[55] See <http://www.nrcs.usda.gov/programs/eqip/>.

Under EQIP, NRCS also offers innovation grants to accelerate the development, transfer, and adoption of innovative technologies and approaches, including those with GHG benefits. USDA awarded 37 percent of its fiscal year 2005 Conservation Innovation Grants funding to energy-related proposals that addressed energy conservation or the production of renewable fuels. USDA estimates that efforts under EQIP could avoid 26.1 Tg CO_2 Eq. by 2012.

Conservation Reserve Program

The Conservation Reserve Program[56] (CRP) encourages farmers to convert environmentally sensitive acreage to native grasses, wildlife plantings, trees, restored wetlands, filter strips, or riparian buffers. USDA's Farm Service Agency (FSA) has issued a new rule that explicitly allows the private sale of carbon credits for lands enrolled in the CRP. FSA has also modified the Environmental Benefits Index used to score and rank offers to enroll land in the CRP to give more points for installing vegetative cover that sequesters more carbon. Finally, FSA has announced it will target 500,000 acres of continuous signup enrollment toward hardwood tree planting. In fiscal year 2005, 50 Tg CO_2 Eq. were sequestered on land enrolled in the CRP—an increase of 2 Tg CO_2 Eq. relative to 2001. Of this increase, 5 percent can be attributed to the policies and initiatives FSA adopted to increase sequestration. USDA estimates the sequestration attributable to these new policies and initiatives will offset U.S. GHG emissions by 3.1 Tg CO_2 Eq. in 2012.

Conservation Security Program

The Conservation Security Program[57] (CSP) is a voluntary program that provides financial and technical assistance to promote conservation on working cropland, pasture, and range land, as well as forested land that is an incidental part of an agriculture operation. NRCS is providing enhancement payments under the CSP to promote energy conservation and the production and use of renewable fuels and electricity.

AgSTAR

Jointly sponsored by EPA, USDA, and DOE, AgSTAR[58] encourages the voluntary use of methane-recovery (biogas) technologies at the confined animal feeding operations that manage manure as liquids or slurries. These technologies reduce methane emissions while achieving other environmental benefits. Although the overall impact of AgSTAR on GHG emissions has been comparatively small on a national scale, livestock producers in the dairy and swine sector have demonstrated that AgSTAR practices can reduce GHG emissions and achieve other pollution control benefits while increasing farm profitability. These practices have been incorporated into USDA's broader technical, conservation, and cost-share programs.

Renewable Energy Systems and Energy Efficiency Improvements Program

Under this program, USDA provides loan guarantees and grants to agricultural producers and rural small businesses to purchase renewable energy systems and improve energy efficiency. Between 2002 and 2006, the program helped finance 272 renewable energy systems (including 11 biodiesel and 7 ethanol refineries, 82 anaerobic digesters, 121 wind projects, 17 solar projects, and 4 geothermal projects) and 165 energy efficiency improvements. USDA estimates that these projects may achieve energy savings amounting to 755 billion Btus (6.6 million barrels) of oil and an estimated reduction in GHG emissions of approximately 1 Tg CO_2 Eq.

Forestry

The U.S. government supports efforts to sequester carbon in both forests and harvested wood products to minimize unintended carbon emissions from forests by reducing the catastrophic risk of wildfires.

Healthy Forest Initiative

Today, between 40.5 and 81 million ha (100 and 200 million ac) of federal lands are at risk of catastrophic wildfires, in large part due to significant changes in forest and woodland structure that have occurred in the last century. Innovative, large-scale management is needed to restore at-risk ecosystems to healthy, resilient conditions. This threat to forests prompted the development of the President's Healthy Forest Initiative, which now includes the *National Fire Plan*[59] and the joint federal–state 10-year *Comprehensive Strategy Implementation Plan.*[60] The goal of these efforts is to increase biomass and wood fiber utilization as an integral component of restoring the Nation's precious forests, woodlands, and rangelands. Coordination among DOI, USDA, and DOE is important to the success of these initiatives, as is working cooperatively with states, tribes, private landowners, nongovernmental organizations, and other interested parties and potential partners. These efforts are expected to lead to substantial co-benefits in terms of reduced air pollution and better air quality, particularly with respect to smoke, particulate matter, and nitrogen oxides.

Forest Land Enhancement Program

USDA's Forest Service administers the Forest Land Enhancement Program[61] (FLEP). Created as part of the Farm Security and Rural Investment Act of 2002, the program provides assistance to nonindustrial private forest landowners for forest stewardship. Through FLEP, the Forest Service, working with states, can promote carbon sequestration with tree planting, forest stand improvements, and agroforestry practices. Program enrollment in fiscal year 2005 was just over 456,000 ha (1.1 million ac), and program-related carbon sequestration is estimated at 0.2 Tg CO_2 Eq.

[56] See <http://www.fsa.usda.gov/dafp/cepd/crp.htm>.
[57] See <http://www.nrcs.usda.gov/Programs/csp/>.
[58] See <http://www.epa.gov/agstar/> and <http://www.rurdev.usda.gov/rbs/farmbill/index.html>.
[59] See <http://www.fireplan.gov/reports/10-YearStrategyFinal_Dec2006.pdf>.
[60] See <http://www.fireplan.gov/reports/11-23-en.pdf>.
[61] See <http://www.fs.fed.us/spf/coop/programs/ loa/flep.shtml>.

Waste Management

The U.S. government's waste management programs reduce municipal solid waste and GHG emissions through energy savings, increased carbon sequestration, and avoided methane emissions from landfill gas—the largest contributor to U.S. anthropogenic methane emissions.

Landfill Methane Outreach Program

The Landfill Methane Outreach Program[62] (LMOP) reduces GHG emissions at landfills by supporting the recovery and use of landfill gas for energy. Capturing and using landfill gas reduces methane emissions directly and reduces CO_2 emissions by displacing the use of fossil fuels through the use of landfill gas as a source of energy. Since the 2002 CAR, LMOP continues to partner with landfill owners and operators, state energy and environmental agencies, utilities and other energy suppliers, corporations, industry, and other stakeholders to lower the barriers to promote cost-effective landfill gas energy projects. LMOP focuses its efforts on smaller landfills not required to collect and combust their landfill gas, as well as larger, regulated operations that are combusting their gas but not using it as a clean energy source.

LMOP has developed a range of technical resources and tools to help the landfill gas industry overcome barriers to energy project development, including feasibility analyses, project evaluation software, a database of more than 1,300 candidate landfills across the country, a project development handbook, commercial and industrial sector analyses, and economic analyses. Due to these efforts, the number of landfill gas energy projects has grown from fewer than 100 in the early 1990s to more than 400 projects today. EPA estimates that LMOP reduced GHG emissions from landfills by about 14 Tg CO_2 Eq. in 2002, and projects reductions of 24 Tg CO_2 Eq. in 2012.

Stringent Landfill Rule

Promulgated under the Clean Air Act in March 1996, the New Source Performance Standards and Emissions Guidelines ("Landfill Rule") require large landfills to capture and combust their landfill gas emissions. The implementation of the rule began at the state level in 1998. Recent data on the rule's impact indicate that increasing its stringency has significantly increased the number of landfills that must collect and combust their landfill gas. EPA estimates that methane reductions in 2002 were 9 Tg CO_2 Eq., and reductions for 2012 may remain about the same.

WasteWise

WasteWise[63] continues to encourage recycling and source reduction. EPA is implementing a number of targeted efforts within this program and is working with organizations to reduce solid waste through voluntary waste reduction activities. New efforts since the 2002 CAR include a *Coal Combustion Products Partnership*[64] and a *GreenScapes*[65] program, which promotes sustainable landscaping techniques, such as increased use of compost and recycled-content materials. EPA continues to promote product stewardship (promoting further waste reduction efforts through voluntary or negotiated agreements with product manufacturers) and its *Pay-As-You-Throw Initiative* to provide information and education on community-based programs that provide cost incentives for residential waste reduction. In addition to program implementation, EPA's *Climate and Waste* program supports outreach, technical assistance, and research efforts on the linkages between climate change and waste management to complement these activities. EPA estimated GHG emission reductions in 2002 were 10 Tg CO_2 Eq. EPA projects reductions could increase to 21 Tg CO_2 Eq. in 2012.

Federal Woody Biomass Working Group

Chartered under the Biomass R&D Board, the Federal Woody Biomass Working Group is working on alternative disposal options for woody biomass resulting from catastrophic events (hurricanes, floods, fire, tornadoes, volcanic eruption, etc). Hurricane Katrina, for example, damaged an estimated 19 billion board feet of timber, much of which will be burned or disposed of in a landfill. The Working Group seeks to use much of this disaster material for bio-based products and bioenergy applications, thus reducing GHG emissions. As bioenergy and wood product markets develop, this effort may serve as an alternative to green waste disposal in landfills.

Cross-Sectoral

Public–private partnerships are an important component of efforts to meet the President's goal of reducing GHG intensity. Several of these cross-sectoral partnership programs are described below, with estimates of expected reductions that would be reported by participants. The estimated reductions for some of these programs have not been included in the scoring of mitigation impacts in this chapter, due to the potential for double counting.

Climate VISION

Climate VISION[66]—Voluntary Innovative Sector Initiatives: Opportunities Now—is a new public–private partnership initiative launched by the federal government in 2003 for the industrial sector to boost its contribution to the President's goal of reducing GHG intensity. Business associations representing 14 energy-intensive industry sectors and The Business Roundtable have become program partners with the federal government and have issued letters of intent to meet specific targets for reducing GHG emissions intensity. These Climate VISION partners include some of the largest companies in America and represent a broad range of industry sectors: oil and gas refining, electricity generation, coal and mineral production and mining, automobile manufacturing, cement, iron and steel, magnesium, aluminum, chemicals, semiconductors, railroads, and forestry products. Climate VISION works with its

[62] See <http://www.epa.gov/lmop/>.
[63] See <http://www.epa.gov/wastewise/>.
[64] See <http://www.epa.gov/epaoswer/osw/conserve/c2p2/>.
[65] See <http://www.epa.gov/greenscapes/>.
[66] See <http://www.climatevision.gov/>.

partners to standardize measuring and monitoring; find cost-effective solutions to reduce energy use and GHG emissions; accelerate R&D; and explore cross-sector efficiency gains to reduce emissions. Based solely on the specific numeric targets in their letters of commitment, Climate VISION partners are estimated conservatively to reduce emissions by about 90 Tg CO_2 Eq. in 2012, including the reductions from the non-CO_2 industry programs discussed previously.[67] This estimate indicates the scale of GHG reductions from this program; however, there may be an overlap with other programs and a potential for double counting.

Voluntary Reporting of Greenhouse Gases Under 1605(b)

Authorized under Section 1605(b) of the Energy Policy Act of 1992, this voluntary program[68] provides a means for utilities, industries, and other entities to establish a public record of their emissions and the results of voluntary measures to reduce, avoid, or sequester GHG emissions. Currently, about 230 U.S. companies and other organizations file reports. The information collected through the program is made available through a public use database that supports educational exchanges, informs public policy development, and encourages public recognition of initiatives to reduce GHGs.

Each year, a report is published highlighting the results of reported activities to reduce emissions. For the 2004 reporting year, 226 U.S. companies and other organizations reported that they had undertaken 2,154 projects to reduce or sequester GHGs. The reported GHG emission reductions for the projects reported included 277 Tg CO_2 Eq. of direct reductions, 92 Tg CO_2 Eq. of indirect reductions, 7 Tg CO_2 Eq. of reductions from carbon sequestration, and 14 Tg CO_2 Eq. of unspecified reductions. These estimates of reductions may overlap with other programs and may result in a potential for double counting.

New general and technical guidelines for reporting will be effective in 2007 for the 2006 reporting year. The new guidelines are intended to strengthen the program by encouraging comprehensive, entity-wide reporting of emissions and emission reductions, including sequestration, and by increasing the measurement accuracy, reliability, and verifiability of reports.

Climate Leaders

EPA launched the Climate Leaders program[69] in 2002 as part of the President's climate change strategy to challenge individual companies to demonstrate leadership by setting aggressive GHG reduction goals for their sectors. Companies that join the partnership receive a number of benefits, such as understanding and managing their emissions, increased identification of cost-effective reduction opportunities, and strategic preparation for the future as the climate change policy discussion evolves. Climate Leader partners set corporate-wide GHG reduction goals and conduct annual inventories of their emissions to measure progress. The program has expanded from its original 12 Charter Partners to more than 100 partners across a number of industrial sectors from heavy manufacturing to banking and retail. The total U.S. GHG emissions of these partners equal nearly 10 percent of total U.S. emissions.

Clean Energy-Environment State Partnership Program

EPA's Clean Energy-Environment State Partnership Program[70] motivates GHG emission reductions as one of several benefits states derive from implementing a comprehensive suite of cost-effective clean energy policies and programs.(U.S. EPA 2006a). (See the following Nonfederal Policies and Measures section for more specific information on a variety of state programs.)

Under the Partnership Program, the 15 member states work across their relevant agencies to develop and implement state-specific action plans, applying existing and new policies and programs to promote energy efficiency, clean distributed generation, renewable energy, and other clean energy strategies that can provide benefits involving GHGs, air quality, public health, energy diversity, and economic growth. To communicate these benefits to other interested state governments, EPA provides technical support and actively shares with them effective strategies and lessons learned. EPA projects that in 2012, this program could contribute 7.3 Tg CO_2 Eq. in GHG reductions.

Federal Energy Management Program

The federal government is the largest single user of energy in the Nation. The Federal Energy Management Program[71] (FEMP) reduces energy use in federal buildings, facilities, and operations by advancing energy efficiency and water conservation, promoting the use of renewable energy, and managing the utility choices of federal agencies. The program accomplishes its mission by leveraging both federal and private resources to provide federal agencies the technical and financial assistance they need to achieve their goals. As of 2005, FEMP had assisted federal agencies in reducing the energy intensity of their buildings by 30 percent using 1985 as a baseline. DOE estimates that realizing FEMP's goal of providing financing and technical assistance to federal agencies to further the use of cost-effective energy efficiency and renewable energy could result in energy savings of nearly 2.2 Tg CO_2 Eq. in 2012.

NONFEDERAL POLICIES AND MEASURES

In addition to the national effort, state and local governments and private and nonprofit organizations are taking a variety of steps that contribute to the overall GHG intensity reduction goal. These nonfederal climate change activities can be an

[67] Projections for partnerships in the aluminum, semiconductor, and magnesium sectors are provided in the Industry: Non-CO_2 section of this chapter under Voluntary Aluminum Industry Partnership and Environmental Stewardship, and are not double counted in the overall projections.
[68] See <http://www.eia.doe.gov/oiaf/1605/frntvrgg.html>.
[69] See <http://www.epa.gov/climateleaders/>.
[70] See <http://www.epa.gov/cleanenergy/stateandlocal/partnership.htm>.
[71] See <http://www1.eere.energy.gov/femp/>.

important factor in the success of emission reduction policies.

State Initiatives

Many state governments have made clean energy, energy efficiency, and climate change initiatives high priorities, recognizing their significant economic and environmental benefits and widespread public support. These states are implementing a wide range of policies and measures to achieve the multiple benefits of minimizing their GHG emissions, encouraging the development of cleaner energy sources, and achieving air quality goals. Appreciating the value of collaboration, states are working across agencies, regionally, and with public- and private-sector stakeholders to develop the most cost-effective mitigation and clean energy strategies. Table 4-1 illustrates the range of actions that states are taking on climate change, as of 2006.

Regional Initiatives

Appreciating the economic value of integrating their strategies, many states have joined to launch regional initiatives to reduce GHG emissions and promote clean energy. Current examples include:

West Coast Governors' Global Warming Initiative[72]—Created by the governors of California, Oregon, and Washington to reduce GHG emissions.

Regional Greenhouse Gas Initiative[73]—Made up of mid-Atlantic and northeastern states to establish a regional CO_2 emissions cap-and-trade program for electric power generators.

Western Governors' Association Clean and Diversified Energy Initiative[74]—Eighteen states working together to meet the goal of clean and diversified energy by developing 30,000 MW of clean electricity by 2015 and increasing energy efficiency by 20 percent by 2020.

Powering the Plains[75]—Five states collaborating on energy and agriculture initiatives that address climate change while promoting regional economic development.

Carbon Sequestration Regional Partnerships[76]—Seven partnerships that represent 40 states, 300 organizations, four Canadian provinces, and three Indian nations that work to determine the most suitable technologies, regulations, and infrastructure needs for carbon capture and storage technology across the United States.

U.S. Mayors Climate Protection Agreement[77]—Agreement by 376 U.S. mayors to reduce GHGs by 7 percent below 1990 levels by 2012.

Climate Action Plans

Some states have developed comprehensive climate change action plans through stakeholder processes that lay out cost-effective strategies for reducing their GHG emissions. Following are some recent examples.

California: Issued April 2006—Developed by the Governor's Climate Action Team, the report identifies 46 specific strategies California can use to meet the governor's near-term target of 1990 levels by 2020 (i.e., a 30 percent reduction of the *Business As Usual* baseline). The report also includes nine key policy recommendations to help ensure the targets are met, along with a preliminary macroeconomic analysis of the recommended strategies that suggests net economic and employment benefits to the state.

Connecticut: Issued February 2005—Developed through the Governor's Steering Committee on Climate Change, the action plan is comprised of 55 measures that are estimated to reduce GHG emissions by 9 Tg CO_2 Eq. in 2010 and 19 Tg CO_2 Eq. in 2020. The plan is designed to help achieve the regional goals set out by the New England Governors/Eastern Canadian Premiers 2001 *Climate Change Action Plan* (NEG/ECP 2001).

Massachusetts: Issued May 2004—Motivated by the joint goals of reducing GHG emissions and improving energy efficiency, the plan is a comprehensive set of near- and mid-term actions that help the environment, energy system, and economy of the Commonwealth. Consistent with the NEG/ECP 2001 *Climate Change Action Plan*, Massachusetts' goals are to reduce GHG emissions to 1990 levels by 2010, reduce emissions to 10 percent below 1990 levels in 2020, and eliminate any dangerous threat to climate in the long run.

New Mexico: Issued December 2006—Developed by the Governor's Climate Change Advisory Group, the report includes policy recommendations for reducing New Mexico's total GHG emissions to 2000 levels by 2012, to 10 percent below 2000 levels by 2020, and to 75 percent by 2050. The report lays out 69 policy recommendations that address energy supply and demand, transportation and land use, agriculture and forestry, and emissions reporting.

Oregon: Issued December 2004—Recommended by the Governor's Advisory Group, the Oregon plan put primary emphasis on real, measurable, meaningful reductions that also were cost-effective and created investment and entrepreneurial opportunities. Its goals are to stop growth of GHG emissions in 2010, reduce GHG emissions to 10 percent below 1990 levels by 2020, and stabilize emissions to at least 75 percent below 1990 levels by 2050. This action plan complements the agenda of the West Coast Governors' Global Warming Initiative.

Lead by Example Programs

Many state governments are implementing programs and policies that are lowering GHGs within their own facilities and operations. States are leveraging their purchasing power, their ability to control significant energy-using resources to test programs, and the often highly visible profile of public facilities to demonstrate clean energy technologies and approaches that save energy

[72] See <http://www.climatechange.ca.gov/westcoast/index.html>.
[73] See <http://www.rggi.org/>.
[74] See <http://www.westgov.org/wga/initiatives/cdeac/index.htm>.
[75] See <http://www.gpisd.net/resource.html?Id=61>.
[76] See <http://www.fe.doe.gov/programs/sequestration/partnerships/index.html>.
[77] See <http://www.ci.seattle.wa.us/mayor/climate/default.htm#what>.

TABLE 4-1 **State Actions on Climate Change**

Several states are implementing a wide range of policies and measures to achieve the multiple benefits of minimizing their GHG emissions, encouraging the development of cleaner energy sources, and achieving air quality goals.

TYPE OF ACTION	PARTICIPATING STATES	NUMBER OF STATES
Individual State Initiatives		
GHG Emission Inventories	Alabama, Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin	42
State Lead by Example Clean Energy Programs	Alabama, Arizona, California, Colorado, Connecticut, Delaware, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, Vermont, Washington, West Virginia, Wisconsin	35
Climate Action Plans	Alabama, Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kentucky, Maine, Maryland, Massachusetts, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Tennessee, Utah, Vermont, Washington, Wisconsin	29
Renewable Energy Portfolio Standards	Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Maine, Maryland, Massachusetts, Minnesota, Montana, Nevada, New Jersey, New Mexico, New York, Pennsylvania, Rhode Island, Texas, Vermont, Washington, Wisconsin	23
Energy Efficiency Public Benefits Funds	Arizona, California, Connecticut, Illinois, Maine, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, Vermont, Wisconsin	18
Renewable Energy Public Benefits Funds	Arizona, California, Connecticut, Delaware, Illinois, Massachusetts, Minnesota, Montana, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Wisconsin	15
Climate Advisory Boards	Alaska, Arizona, California, Connecticut, Illinois, Montana, New Mexico, New York, North Carolina, Oregon, Utah, Vermont	12
GHG Emission Targets	Arizona, California, Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont	12
Vehicle GHG Emission Standards	California, Connecticut, Maine, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Washington	11
Energy Efficiency Portfolio Standards	California, Colorado, Connecticut, Hawaii, Illinois, Nevada, New Jersey, Pennsylvania, Texas, Vermont	10
Mandatory CO_2 Reporting for Stationary Sources	Connecticut, Maine, Massachusetts, New Jersey, Wisconsin	5
Power Plant CO_2 Emission Cap	Massachusetts, New Hampshire, Oregon, Washington	4
GHG Emission Registries	California, New Hampshire, Wisconsin	3
Baseload Power GHG Performance Standard	California	1
Statewide GHG Emission Cap	California	1
Regional Initiatives		
Western Governors' Association Clean and Diversified Energy Initiative	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, Wyoming	18
Eastern Climate Registry	Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont	10
Midwest GHG Registry	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin	8

TABLE 4-1 (Continued) **State Actions on Climate Change**

TYPE OF ACTION	PARTICIPATING STATES	NUMBER OF STATES
Regional Initiatives (Continued)		
Regional Greenhouse Gas Initiative	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Vermont (Pennsylvania and Rhode Island are observers)	8
New England Governors: Climate Change Action Plan	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	6
Powering the Plains	Iowa, Minnesota, North Dakota, South Dakota, Wisconsin	5
West Coast Governor's Global Warming Initiative	California, Oregon, Washington	3
Southwest Climate Change Initiative	Arizona, New Mexico	2

Note: This table includes completed actions. Other states may have initiatives in progress or being considered.

and reduce GHGs. This can take many forms: adopting energy efficiency savings goals for buildings; procuring energy-efficient equipment and green power for public facilities; implementing "green fleets" programs, purchasing alternative fuel vehicles, and reducing vehicle trips; and establishing financing mechanisms, providing technical assistance, and training staff to help ensure energy-saving goals are achieved. Currently, 35 states have some form of Lead by Example program. Some successes of these state efforts follow.

New Hampshire's Building Energy Conservation Initiative[78]—Reducing energy costs in 10 state buildings through energy retrofits and building upgrades. Uses a "paid from savings" procedure, also known as Performance Contracting, in which energy savings pay for building retrofits and upgrades. Overall avoided energy costs now exceed $200,000 annually.

New Jersey's Green Power Purchasing Program[79]—Helping support the state goal of reducing GHGs to 3.5 percent below 1990 levels by 2005, in part, through an innovative aggregated green power purchasing program that supplies 500 million kWh of green power to more than 200 facilities statewide. The program has expanded green energy markets in the state and has increased private-sector green power purchases. The reduced CO_2 emissions are equivalent to removing 32,500 cars from the road for one year.

Local Initiatives

Cities for Climate Protection Campaign

In addition to contributing to their state GHG initiatives, more than 150 U.S. cities and counties representing more than 50 million people are participating in the International Council for Local Environmental Initiatives' Cities for Climate Protection Campaign.[80] The program offers training and technical assistance to cities, towns, and counties for projects focused on reducing GHG emissions. Actions implemented by participating cities are reducing emissions by 20 Tg CO_2 Eq. annually.

Heat Island Reduction Initiative

Through its Heat Island Reduction Initiative (HIRI),[81] EPA has been working with state and local officials, researchers, and industry and nonprofit groups to reduce summertime temperatures by promoting use of ENERGY STAR cool-roof products and increasing vegetative cover. HIRI has been hosting quarterly forums on heat island research and implementation activities, as well as supporting heat island policy workshops involving eight U.S. cities.

Private-Sector and NGO Initiatives

Several innovative efforts of private-sector and nonprofit initiatives demonstrate the impact that organizations can have on climate change by making a commitment to a healthier environment.

Climate Savers

Climate Savers[82] is an initiative organized by the World Wildlife Fund in 2000 to mobilize companies to cut CO_2 emissions. Collins, Sagawa and Lafarge have joined Johnson & Johnson, IBM, Nike, and Polaroid in participating. Each company has pledged to reduce its worldwide GHG emissions by 7 percent below 1990 levels by 2010. The program includes an independent verification process.

Ceres' Investor Network on Climate Risk

In 2002, Ceres launched the Sustainable Governance Project to raise global climate change as a significant risk to the long-term value of corporations and the viability of financial assets. In November 2003, Ceres organized the Institutional Investor Summit on Climate Risk and established the Investor Network on Climate Risk (INCR).[83] Through INCR, Ceres has mobilized some of the Nation's largest institutional investors to focus on companies' climate risk. INCR

[78] See <http://www.nh.gov/oep/programs/energy/beci.htm>.
[79] See <http://www.state.nj.us/dep/dsr/bscit/GreenPower.pdf>.
[80] See <http://www.iclei.org/index.php?id=800>.
[81] See <http://www.epa.gov/heatisland/index.html>.
[82] See <http://www.worldwildlife.org/climate/projects/climateSavers.cfm>.
[83] See <http://www.ceres.org/>.

collaborates with investors and the financial community through briefings, meetings, and publication and distribution of reports. Ceres also convenes high-emitting companies in dialogues with investors and environmental groups, and coordinates the global warming shareholder campaign.

Green Power Market Development Group

The Green Power Market Development Group[84] is a collaboration between the World Resources Institute and 13 participating companies. NatureWorks, LLC, Starbucks, and Staples recently joined original members Alcoa, Delphi, Dow, DuPont, FedEx, Kinko's, General Motors, IBM, Interface, Johnson & Johnson, and Pitney Bowes. The group's goal is to develop corporate markets for 1,000 MW of new, cost-competitive green power by 2010. The group develops and publishes an ongoing series of white papers that focus on market development issues, including the design of innovative green power purchasing vehicles.

Chicago Climate Exchange

The Chicago Climate Exchange (CCX)[85] includes more than 25 member companies that agreed to reduce their GHG emissions by 1 percent per year from 2003 through 2006. Companies achieve this reduction target through internal reductions, emissions trading with other members, purchasing GHG offsets from qualifying projects, or a combination of these approaches. Continuous electronic trading of GHG emission allowances and offsets began on December 12, 2003. The tradable Carbon Financial Instruments employed in CCX are Exchange Allowances and Exchange Offsets. Exchange Allowances are issued on the basis of forest carbon sequestration and reductions in electricity use. Exchange Offsets are generated by qualifying mitigation projects and are registered with CCX by Exchange Participant Members.

Business Environmental Leadership Council

The Pew Center's Business Environmental Leadership Council[86] is a group of leading companies worldwide that are responding to the challenges posed by climate change. Membership has grown to include 38 corporations, 27 of whom have set public GHG reduction targets.

PowerSwitch!

In February 2004, Austin Energy (Texas), Burlington Electric Department (Vermont), Florida Power and Light (Florida), Sacramento Municipal Utility District (California), and Waverley Light and Power (Iowa) joined the World Wildlife Fund's PowerSwitch! campaign.[87] Each of the companies agreed to call for binding limits on CO_2 emissions from the power sector. In addition, these companies are voluntarily reducing GHG emissions by committing to achieve at least one of three PowerSwitch! goals by 2020: (1) using renewable energy to generate 20 percent of power sold, (2) increasing energy efficiency by 15 percent, or (3) phasing out the least efficient half of energy generation (or production) from coal.

Climate RESOLVE

Sponsored by The Business Roundtable, Climate RESOLVE[88] seeks to encourage 100 percent of the Roundtable membership to undertake voluntary actions to control GHG emissions. Roundtable CEOs believe that motivated, forward-looking companies working in partnership with government can find many practical, cost-effective opportunities to improve energy efficiency and reduce, avoid, offset, or sequester GHG emissions—without the serious economic disruption caused by mandatory GHG controls. Approximately 70 percent of Roundtable companies from every sector of the economy have signed up for Climate RESOLVE.

LONG-TERM MEASURES

In addition to implementing policies and measures that reduce emissions intensity in the near term, the U.S. government is committed to investing in relevant R&D over the long term. These R&D efforts are the key to discovering breakthrough technologies that are needed for emission reductions beyond what is achievable at present. The long-term component of U.S. climate change strategy—discussed in detail in Chapter 8, Research and Systematic Observation—includes the following programs: Carbon Sequestration Regional Partnerships,[89] Generation IV Nuclear Energy Systems Initiative,[90] Nuclear Hydrogen Initiative,[91] Advanced Fuel Cycle Initiative,[92] Global Nuclear Energy Partnership,[93] Clean Automotive Technology,[94] Hydrogen Technology,[95] and High-Temperature Superconductivity.[96]

INTERNATIONAL MEASURES

In addition to implementing a broad portfolio of domestic programs, the United States has committed to working globally with developed and developing countries on climate change issues. Because climate change is a global concern, international cooperation is necessary to make discernible progress. The United States has signed a number of bilateral agreements and participates in numerous multilateral efforts, including the Asia-Pacific Partnership and the Methane to Markets Partnership. Several federal agencies, including DOE, EPA, the U.S. Agency for International Development, and USDA, are engaged in technology transfer programs with developing and transitional countries to provide assistance in limiting GHG emissions. The international technology development collaborations are described in more detail in Chapter 8, Research and Systematic Observation, and those on technology transfer in Chapter 7, Financial Resources and Transfer of Technology.

[84] See <http://www.thegreenpowergroup.org/us.cfm>.
[85] See <http://www.chicagoclimatex.com/>.
[86] See <http://pewclimate.org/companies_leading_the_way_belc/>.
[87] See <http://powerswitch.panda.org/news_publications/news_detail.cfm?uxNewsID=13042>.
[88] See <http://www.businessroundtable.org/TaskForces/TaskForce/issue.aspx?qs=6EC5BF159FF49514481138A6DF6185 1159169FEB56A3FB0AE>.
[89] See <http://www.fe.doe.gov/programs/sequestration/partnerships/index.html>.
[90] See <http://gen-iv.ne.doe.gov/ and http://www.ne.doe.gov/infosheets/genIV.pdf>.
[91] See <http://www.ne.doe.gov/infosheets/hydrogen.pdf>.
[92] See <http://www.ne.doe.gov/infosheets/afci.pdf>.
[93] See <http://www.gnep.energy.gov/>.
[94] See <http://www.epa.gov/otaq/technology/>.
[95] See <http://www.eere.energy.gov/hydrogenandfuelcells/>.
[96] See <http://www.oe.energy.gov/randd/supercon.htm>.

TABLE 4-2 **Summary of U.S. Actions to Reduce Greenhouse Gas Emissions** (Tg CO_2 Eq.)[1]

Policy or Measure	Objective and/or Activity Affected	GHG Affected	Type of Instrument	Status	Implementing Entities	Estimated Mitigation Impact for[1] 2002	2012	2020
Energy: Commercial and Residential[2]								
Commercial Building Integration (includes Rebuild America)	Realizes energy-saving opportunities provided by whole-building-system-design approach during new construction and major renovation of existing commercial buildings.	CO_2	Research; Regulatory	Implemented	DOE	NA	0.5	3.1
Emerging Buildings Technologies*	Conducts R&D on building components and design tools, and issues standards and test procedures for a variety of appliances and equipment.	CO_2	Information; Research	Implemented	DOE	0.0	4.4	25.4
ENERGY STAR for the Commercial Market	Promotes the improvement of energy performance in commercial buildings.	CO_2	Voluntary Agreement	Implemented	EPA	35.2	64.2	93.5
ENERGY STAR for the Residential Market	Promotes the improvement of energy performance in residential buildings beyond the labeling of products.	CO_2	Voluntary; Outreach	Implemented	EPA	0.2	7.3	44.0
ENERGY STAR-Labeled Products	Provides labels to distinguish energy-efficient products in the marketplace.	CO_2	Voluntary; Outreach	Implemented	EPA/DOE	38.1	102.7	148.5
Residential Appliance Standards	Conducts analyses of and develops, reviews, and updates efficiency standards for most major household appliances and major commercial building technologies and equipment.	CO_2	Regulatory	Implemented	DOE	NA	5.1	17.3
Residential Building Integration	Enables industry to adopt systems engineering approaches to the design and construction of new housing by funding, developing, demonstrating, and deploying housing that integrates energy efficiency technologies and practices.	CO_2	Voluntary; Research; Education	Implemented	DOE	NA	3.8	9.5
State Energy Programs	Strengthens and supports the capabilities of states to promote energy efficiency and to adopt renewable energy technologies, helping the Nation achieve a stronger economy, a cleaner environment, and greater energy security.	CO_2	Economic; Information	Implemented	DOE	0.0	2.5	2.6
Weatherization Assistance	Enables low-income families to permanently reduce their energy bills by making their homes more energy efficient.	CO_2	Economic; Deployment	Implemented	DOE	1.1	3.9	6.0

[1] Estimates of mitigation impacts of programs are provided by the agency responsible for each individual program, based on the agency's experience and assumptions related to the implementation of voluntary programs. These estimates may include assumptions about the continued or increased participation of partners, development and deployment goals, and/or whether the necessary commercialization or significant market penetration is achieved.

[2] Estimates of mitigation impacts for individual policies or measures should not be aggregated to the sectoral level, due to possible synergies and interactions among policies and measures that might result in double counting.

TABLE 4-2 (Continued) **Summary of U.S. Actions to Reduce Greenhouse Gas Emissions** (Tg CO_2 Eq.)[1]

Policy or Measure	Objective and/or Activity Affected	GHG Affected	Type of Instrument	Status	Implementing Entities	Estimated Mitigation Impact for[1] 2002	2012	2020
Energy: Industrial[2]								
Best Practices Program	Offers industry the tools to improve plant energy efficiency, enhance environmental performance, and increase productivity.	All	Voluntary; Information	Implemented; Undergoing Revision	DOE	8.1	16.9	49.1
ENERGY STAR for Industry	Enables industrial companies to evaluate and cost-effectively reduce energy use.	CO_2	Voluntary Agreement	Implemented	EPA	13.6	21.3	36.7
Industrial Assessment Centers	Assesses and provides recommendations to manufacturers by identifying opportunities to improve productivity, reduce waste, and save energy.	All	Information; Research	Implemented; Undergoing Revision	DOE	8.4	17.6	51.3
Industrial Technologies	Addresses the critical technology challenges partners face for developing materials and production processes.	All	Information; Research	Implemented; Undergoing Revision	DOE	8.4	17.6	51.3
Energy: Supply[2]								
Carbon Sequestration*	Develops new technologies for addressing cost-effective management of CO_2 emissions from the production and use of fossil fuels.	CO_2	Research	Implemented	DOE	0.0	30.3	34.0
Clean Energy Initiative; Green Power Partnership; Combined Heat and Power Partnership	Removes market barriers to increased penetration of cleaner, more efficient energy supply.	CO_2	Voluntary; Education; Technical Assistance	Implemented	EPA	0.7	29.3	73.3
Distributed Energy Resources	Focuses on technology development and the elimination of regulatory and institutional barriers to the use of distributed energy resources.	All	Information; Research; Education; Regulatory	Implemented	DOE	12.1	23.8	57.2
Renewable Energy Commercialization: Wind; Solar; Geothermal; Biomass	Develops clean, competitive power technologies using renewable resources.	All	Research	Implemented	DOE	NA	5.2	153.5
Transportation[2]								
Aircraft Fuel Efficiency	Improves aircraft/engine technology and operational procedures, and enhances the airspace transportation system to reduce aviation's contribution to CO_2 emissions.	CO_2	Technical; Research	Implemented	DOT	NA	NA	NA
Biofuels and Biorefinery Systems	Fosters research on and development of advanced technologies that will transform the Nation's domestic biomass resources into affordable biofuels and high-value bioproducts.	All	Information; Research	Implemented	DOE	0.0	0.6	5.9

TABLE 4-2 (Continued) **Summary of U.S. Actions to Reduce Greenhouse Gas Emissions** (Tg CO_2 Eq.)[1]

Policy or Measure	Objective and/or Activity Affected	GHG Affected	Type of Instrument	Status	Implementing Entities	Estimated Mitigation Impact for[1] 2002	2012	2020
Congestion Mitigation and Air Quality Improvement Program	Provides states with funds to reduce congestion and improve air quality through transportation control measures and other strategies.	CO_2	Voluntary Agreement	Implemented	DOT	NA	NA	NA
Corporate Average Fuel Economy	Raises the fuel economy standard for minivans, pickup trucks, SUVs, and other light trucks from the current 8.8 kpl (20.7 mpg) to 9.4 kpl (22.2 mpg) by 2007.	CO_2	Regulatory	Implemented	DOT	0.0	41.8	76.7
FreedomCAR and Fuel Partnership and Vehicle Technologies Program (includes Clean Cities)	Advances high-risk research needed to develop the necessary technologies, such as fuel cells and advanced hybrid propulsion systems, to provide a full range of affordable cars and light trucks that are free of foreign oil and harmful emissions—and that do not sacrifice freedom of mobility and freedom of vehicle choice.	CO_2	Research	Implemented	DOE	0.0	11.5	72.0
Renewable Fuel Standard	Implements the Energy Policy Act 2005 requirement to increase the amount of renewable fuel used in transportation to 7.5 billion gallons by 2012.	CO_2	Regulatory	New; Being Implemented	EPA	NA	NA	NA
SmartWay Transport Partnership	Accelerates development of fuel-savingtechnology and practices in transport and freight operations.	CO_2	Voluntary Agreement; Technical Assistance; Information; Education; Outreach	Implemented	EPA	7.7	33.0	43.0
Industry (Non-CO_2)[2]								
Coalbed Methane Outreach Program	Reduces methane emissions from U.S. coal mining operations through cost-effective means.	CH4	Information; Education; Outreach	Implemented	EPA	6.2	10.6	12.1
Environmental Stewardship Initiative	Limits emissions of HFCs, PFCs, and SF_6 in industrial applications.	High GWP	Voluntary Agreement	Implemented	EPA	4.8	35.6	54.3
HFC-23 Partnership	Encourages reduction of HFC-23 emissions through cost-effective practices and technologies.	HFC-23	Voluntary Agreement	Implemented	EPA	16.5	16.5	15.4
Mobile Air Conditioning Climate Protection Partnership	Identifies near-term opportunities to improve the environmental performance of mobile air conditioners, and promotes cost-effective designs and improved service procedures to minimize emissions from mobile air conditioning systems.	CO_2, HFC-134a	Voluntary; Research	Implemented	EPA	0.0	5.5	24.5
Natural Gas STAR Program	Reduces methane emissions from U.S. natural gas systems through the widespread adoption of industry best management practices.	CH_4	Voluntary Agreement	Implemented	EPA	20.2	30.8	46.9

TABLE 4-2 (Continued) **Summary of U.S. Actions to Reduce Greenhouse Gas Emissions** (Tg CO_2 Eq.)[1]

Policy or Measure	Objective and/or Activity Affected	GHG Affected	Type of Instrument	Status	Implementing Entities	Estimated Mitigation Impact for[1] 2002	2012	2020
Significant New Alternatives Program	Facilitates smooth transition away from ozone-depleting chemicals in industrial and consumer sectors.	High GWP	Regulatory; Information	Implemented	EPA	26.0	149.6	222.9
Voluntary Aluminum Industry Partnership	Encourages reduction of CF_4 and C_2F_6 where technically feasible and cost-effective.	PFCs	Voluntary Agreement	Implemented	EPA	6.6	10.3	10.3
Voluntary Code of Practice for HFC & PFC Fire Protection Agents	Minimizes nonfire emissions of HFCs and PFCs used as fire-suppression alternatives, and protects people and property from the threat of fire through the use of proven, effective products and systems.	HFCs, PFCs	Voluntary Agreement	Implemented	EPA	NA	NA	NA
Agriculture[2,3]								
AgSTAR	Promotes practices to reduce GHG emissions at U.S. farms.	CH_4	Information; Education; Outreach	Implemented	EPA/USDA	NA	NA	NA
Environmental Quality Incentives Program; Conservation Innovation Grants	Under EQIP, NRCS offers innovation grants to livestock producers and owners of working farmlands to accelerate the development, transfer, and adoption of innovative technologies and approaches, including those that deliver GHG benefits and improve the quality of nutrient management systems.	All	Partnerships/ Financial Assistance	Implemented	USDA	0.0	26.1	26.1
Conservation Reserve Program	Encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to native grasses, wildlife plantings, trees, filter strips, and riparian buffers.	CO_2	Technical/ Financial Assistance	Implemented	USDA	0.0	3.1	7.8
Conservation Security Program	Provides financial and technical assistance to promote conservation on working cropland, pasture, and range land, as well as forested land that is an incidental part of an agriculture operation.	CO_2, CH_4	Technical/ Financial Assistance	Implemented	USDA	NA	NA	NA
Commodity Credit Corporation Bioenergy Program**	Encourages bioenergy production through economic incentives to commodity producers.	CO_2	Economic	Implemented	USDA	NA	NA	NA
Rural Development Renewable Energy Programs***	Provides economic incentives to commodity producers to install renewable energy systems.	CO_2	Economic	Implemented	USDA	0.0	1.2	1.2
Forestry[2]								
Forest Land Enhancement Program	Provides assistance to nonindustrial private forest landowners for forest stewardship, with explicit carbon sequestration goals.	CO_2	Technical/ Financial Assistance	Implemented	USDA	0.0	0.2	0.2

TABLE 4-2 (Continued) **Summary of U.S. Actions to Reduce Greenhouse Gas Emissions** (Tg CO_2 Eq.)[1]

Policy or Measure	Objective and/or Activity Affected	GHG Affected	Type of Instrument	Status	Implementing Entities	Estimated Mitigation Impact for[1] 2002	2012	2020
Waste Management[2]								
Landfill Methane Outreach Program	Reduces methane emissions from U.S. landfills through cost-effective means.	CH_4	Voluntary Agreements; Information; Education; Outreach	Implemented	EPA	14.3	24.6	30.8
Stringent Landfill Rule	Reduces methane/landfill gas emissions from U.S. landfills.	CH_4	Regulatory	Implemented	EPA	8.7	9.5	9.9
WasteWise	Encourages recycling, source reduction, and other progressive integrated waste management activities for the purpose of reducing GHG emissions.	All	Voluntary Agreements; Technical Assistance; Information; Research	Implemented	EPA	10.3	20.9	33.0
Cross-Sectoral[2]								
Clean Energy-Environment State Partnership Program	Motivates GHG emission reductions as one of several benefits states derive from implementing a comprehensive suite of cost-effective clean-energy policies and programs.	All	Information; Education; Research	Implemented	EPA	7.3	7.3	7.3
Climate Leaders	Assists companies with developing long-term, comprehensive climate change strategies.	All	Voluntary Agreement	Implemented	EPA	NA	NA	NA
Climate VISION	Works with partners to measure and monitor emissions, find cost-effective solutions to reduce energy use and GHG emissions, accelerate R&D, and explore cross-sector efficiency gains to reduce emissions.	All	Voluntary	Implemented	DOE/EPA/ USDA/DOT	NA	NA	NA
Federal Energy Management Program	Promotes energy efficiency and renewable energy use in federal buildings, facilities, and operations.	All	Economic; Information; Education	Implemented	DOE	0.0	2.2	3.7
Voluntary Reporting of Greenhouse Gases (1605(b))	Provides a means for organizations and individuals to record the results of voluntary measures to reduce, avoid, or sequester GHG emissions.	All	Voluntary Agreement	Implemented	DOE/ EPA/ USDA	NA	NA	NA

[1] Estimates of mitigation impacts of programs are provided by the agency responsible for each individual program, based on the agency's experience and assumptions related to the implementation of voluntary programs. These estimates may include assumptions about the continued or increased participation of partners, development and deployment goals, and/or whether the necessary commercialization or significant market penetration is achieved.

[2] Estimates of mitigation impacts for individual policies or measures should not be aggregated to the sectoral level, due to possible synergies and interactions among policies and measures that might result in double counting.

[3] Estimates presented here reflect mitigation impacts due to GHG measures and policies implemented since 2002 in USDA's conservation and renewable energy programs.

NA: Not applicable for long-term, R&D, and umbrella programs.

* These are long-term research efforts discussed in Chapter 8. To allow for a conservative estimate of overlap between Chapters 4 and 5, estimated impacts from technologies expected to penetrate the market by 2012 are included in this table.

** This program ended in 2006.

***Although no additional renewable energy projects are planned under this program after 2006, renewable energy systems implemented under this program are expected to have GHG benefits through 2020. The estimates shown here reflect only wind energy projects implemented between 2002 and 2006.

5 Projected Greenhouse Gas Emissions

On February 14, 2002, President Bush announced his Global Climate Change policy, committing to reduce the greenhouse gas (GHG) intensity of the U.S. economy by 18 percent by 2012. GHG intensity measures the ratio of GHG emissions to economic output. This approach focuses on reducing the growth of GHG emissions, while sustaining the economic growth needed to finance investment in new, clean energy technologies. It sets the United States on a path to slow the growth of GHG emissions, and—as the science justifies—to stop and then reverse that growth. This chapter provides projections for national emissions under the Global Climate Change policy.

MEETING THE PRESIDENT'S TARGET FOR REDUCING U.S. GHG INTENSITY

The President's commitment to reducing GHG intensity represented a 4 percentage point improvement in absolute terms over the projected U.S. *Business As Usual* GHG intensity improvement.[1] This corresponded to a reduction in GHG emissions of 367 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.) by 2012 relative to *Business As Usual* projections, and more than 1,833 Tg CO_2 Eq. in cumulative GHG reductions between 2002 and 2012.[2] The President's Global Climate Change policy focuses on reducing emissions through technology improvements and dissemination, demand-side efficiency gains, voluntary programs with industry, and shifts to cleaner fuels.

The President's GHG intensity improvement target was developed using the best available data, including GHG projections from the U.S. Environmental Protection Agency (EPA), and GHG and economic projections from the Energy Information Administration (EIA), an independent statistical and analytical agency within the U.S. Department of Energy (DOE). These data have been updated in the present report to reflect actual GHG emissions and gross domestic product (GDP) data for the years 2002 through 2004 and projections of both emissions and economic growth based on the latest available U.S. government analyses from EIA and EPA. The most recent projections published in the *Annual Energy Outlook 2006* (AEO) (U.S. DOE/EIA 2006a) incorporate the effects of many policies enacted through October 2005 and also use much higher oil prices than in previous analyses. These updates result in lower projected energy consumption and lower CO_2 emission projections, as compared to previous editions of the AEO.

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[1] At the time of President Bush's announcement in 2002, the estimated GHG intensity of the U.S. economy was 671 metric tons of carbon dioxide equivalent (t CO_2 Eq.) emissions per million dollars of gross domestic product (GDP). The GHG intensity was projected to decrease to 578 t CO_2 Eq. emissions per million dollars of GDP in 2012 under a *Business As Usual* scenario based on existing polices and efforts—a decline of 14 percent. See <www.whitehouse.gov/news/releases/2002/02/addendum.pdf>.

[2] In the metric used at the time of the President's announcement, million metric tons of carbon equivalents (MMTCE), this corresponded to a reduction of more than 100 MMTCE in 2012 and more than 500 MMTCE from 2002 through 2012, over and above the *Business As Usual* projection. (One teragram (Tg) equals one million metric tons (Mt). Carbon dioxide equivalents can be converted to carbon equivalents by multiplying by the ratio of their atomic masses (12/44): 367 Tg CO_2 Eq. = 367 Mt CO_2 Eq. = 100 MMTCE.)

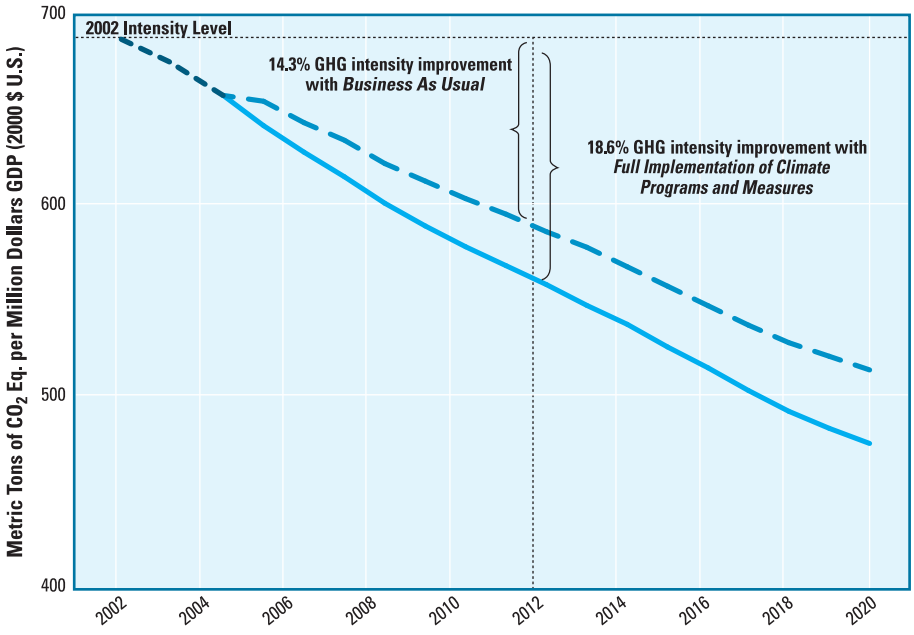
Given *Full Implementation of Climate Programs and Measures*, and based on recent U.S. government forecasts that reflect current economic conditions, the United States is projected to exceed the President's 18 percent goal by 2012. The gross 686 t CO_2 Eq. emissions per million dollars of GDP emitted in 2002 are projected to be lowered to 559 t CO_2 Eq. per million dollars GDP in 2012—an 18.6 percent reduction in GHG intensity. Over the same period from 2002 to 2012, while GHG intensity is declining, total gross GHG emissions are expected to rise by 11 percent to 7,709 Tg CO_2 Eq.

Since 2002, the President has expanded existing measures and has implemented new short- and long-term measures to reduce GHG intensity. The short-term measures, such as voluntary reductions of methane and fluorinated gases from industry and tax incentives on renewables and cogeneration, are expected to further reduce GHG intensity by 2012. Using the latest available data, these additional measures—as outlined in Chapter 4 of this report—are accounted for in the *Full Implementation of Climate Programs and Measures* baseline. The calculation of overall reductions in GHG emissions due to the federal climate programs is based on the methodology originally presented in the 2002 *Climate Action Report* (CAR) (U.S. DOS 2002).

Based on actual data from 2002 through 2004 (U.S. EPA/OAP 2006c), Figure 5-1 contains two projections: the GHG intensity associated with the *Business As Usual* projection and the additional GHG intensity improvement resulting from the *Full Implementation of Climate Programs and Measures*.[3] The influence of U.S. policies and measures in encouraging the development and use of cleaner, more efficient technologies can be seen in the reduction of GHG intensity over the period examined. Other important factors improving U.S. GHG intensity include the substitution of fuels that emit lower volumes of GHGs and changes in the composition of GDP to goods and services with fewer fuel inputs.

FIGURE 5-1 Historical and Projected U.S. Greenhouse Gas Intensity

U.S. greenhouse gas intensity under *Full Implementation of Climate Programs and Measures* is projected to meet the President's target for 2012. The GHG emission reduction in 2012 is projected to be 407 Tg CO_2 Eq. (111 MMTCE), and the cumulative GHG emission reduction from 2002 through 2012 is projected to be 2,225 Tg CO_2 Eq. (607 MMTCE), relative to projected emissions under *Business As Usual* conditions. From 2002 through 2012, GHG emissions are expected to rise by 11 percent to 7,709 Tg CO_2 Eq.



Note: One teragram (Tg) equals one million metric tons.

ASSUMPTIONS USED TO ESTIMATE FUTURE GREENHOUSE GAS EMISSIONS

EIA's AEO 2006 provided the baseline projection of energy-related CO_2 emissions (U.S. DOE/EIA 2006a). This baseline partially reflects the impact of the energy-related policies and measures discussed in Chapter 4. Federal agencies with direct responsibility for implementing polices and measures adjusted the AEO 2006 reference case to reflect their own estimates of the expected impacts of their programs. EPA prepared the emission projections for source categories other than CO_2 emissions resulting from fossil fuel consumption (U.S. EPA/OAP 2006b), and the U.S. Department of Agriculture (USDA) prepared the estimates of carbon sequestration rates based on the carbon sequestration models developed for the U.S. inventory (U.S. EPA/OAP 2002). The projections reflect long-run trends and do not attempt to mirror short-run departures from those trends.

The AEO 2006 presents medium-term scenarios of energy supply, demand, and prices through 2030 (U.S. DOE/EIA 2006a), based on results from EIA's National Energy Modeling System (NEMS), a publicly shared and well-documented model. The AEO 2006 cases reflect an integrated analysis of CO_2 emissions, accounting for interaction and feedback effects in energy markets and the economy.

[3] Some of the impact of existing national policies and programs is already being captured in the *Business As Usual* projection, as described in the following section of this chapter.

In some cases, however, the AEO uses assumptions about technology diffusion and adoption rates that differ from the assumptions used for the independent policies and measures estimates in Chapter 4 of this report.

The reported effects of the individual policies and measures in Chapter 4 are based on assumptions regarding the adoption and impacts of each measure. Because this approach differs from the approach implicit in NEMS, a precise mapping to the emission reductions from individual policies and measures against the aggregate estimates developed in the AEO cases is not possible. There are two distinct challenges. First, the energy-related measures described in Chapter 4 are already partially reflected in the AEO results (for example, the 2003 corporate average fuel economy (CAFE) increase for light trucks). Second, the impacts reported in Chapter 4, which are typically estimated on a stand-alone basis, recognize fewer interactions and competitive effects within and among the economic sectors in which the individual measures are applied. In contrast to the NEMS model, which addresses interaction effects between a comprehensive set of economic variables and policies, the models used in projecting the direct impacts of Chapter 4 policies and measures are partial equilibrium models that do not represent the economy as a whole. The Chapter 4 programs and measures effects do not reflect interactions between competitive alternatives, which could include overlapping, double counting, or synergistic effects. To address these challenges, the mitigation impacts of all policies and measures as reported in Chapter 4 were adjusted downward by 25 percent or greater[4] and then subtracted from the appropriate baseline to generate the projections in this chapter. This adjustment was necessary to address the possible interactions between the policies and measures as well as uncertainty in market responses, and the potential for some portion of the mitigation impact of the policies and measures to already be captured in the *Business As Usual* baseline.

TABLE 5-1 **Comparison of the 2002 CAR and the 2006 CAR Assumptions and Model Results for the Year 2020**

Several measures of the U.S. economy generate energy consumption and related carbon emission estimates. This table compares the values used in the 2002 CAR to those relied upon for this report.

Factors	Assumptions for 2020	
	2002 CAR	2006 CAR
Real GDP (billions of 2000 dollars)	18,136	17,541
Population (millions)	325	337
Energy Intensity (Btus per 2000 dollar GDP)	8,712	6,877
Light-Duty Vehicle Miles Traveled (billions)	3,631	3,474
Energy Commodity Price/Imported Crude Oil Price (2000 dollars/barrel)	24.68	41.24
Wellhead Natural Gas (2000 dollars/1,000 cubic feet)	3.26	4.49
Minemouth Coal (2000 dollars/ton)	12.79	18.52
Average Price Electricity (2000 cents/kWh)	6.50	6.64
Average Price Gasoline (2000 dollars/gallon)	1.40	1.90

Source: U.S. DOE/EIA 2006a.

The AEO 2006 projects a declining ratio of emissions to GDP by incorporating the enacted regulatory and fiscal policies as well as the impacts—including costs—of technology dissemination.[5] The degree of technology improvement reflected in the projections is internally generated in the modeling process based on EIA's judgment about the availability, cost, and performance of technologies, their rates of adoption, and their potential for efficiency improvement. The assumptions under which the AEO 2006 estimates were prepared include real GDP growth of 3.0 percent annually from 2004 through 2030, without specific regard to interim business cycles. Based on the AEO 2006 reference case estimates, the average U.S. cost of imported crude oil in real 2000 dollars is projected to be just over $41 per barrel by 2020.[6] To support projections of increased demand, natural gas supplies are supplemented with growing imports—in particular, liquefied natural gas—and domestic unconventional production. The natural gas wellhead price is projected to be $4.49 per thousand cubic feet in 2020 in real 2000 dollars. EIA's projection assumes that current laws and regulations will continue in force, but it does not anticipate measures not yet enacted or implemented. Table 5-1 presents several measures of the U.S. economy that generate estimates of energy consumption and related carbon emissions for 2020, and compares the values used in the 2002 CAR to those relied upon for this report (2006 CAR). In this report, 2020 real GDP is somewhat lower, energy intensity per dollar of GDP is notably lower, and the prices of natural gas and crude oil are higher than the levels assumed in the 2002 CAR.

[4] The effects of the non-CO_2 policies and measures in reducing emissions as presented in Chapter 4 were adjusted downward by 25 percent to generate the projections for 2012 and 2020 presented in this chapter. The effects of the CO_2 policies and measures were adjusted downward by 25 percent in 2012 and by 50 percent in 2020 to reflect an increasing amount of energy efficiency reductions included in the AEO 2006 reference case.

[5] A description of the policies and measures and technology assumptions embodied in the AEO projections can be found at <www.eia.doe.gov>.

[6] While current oil prices are higher, the AEO 2006 reference case does not project the recent growth trend to continue. Alternatively, the AEO 2006 high-price case projects the imported crude oil price to be $73 per barrel in 2020. If this 2007 CAR analysis were to use the AEO 2006 high-price case, energy consumption would likely be lower, resulting in lower U.S. GHG emissions than the projections presented in this chapter.

Emission projections in this report are converted to Tg CO_2 Eq., in keeping with the reporting guidelines of the United Nations Framework Convention on Climate Change (UNFCCC). To analyze the non-CO_2 gases in the same framework as CO_2, this report uses the 100-year global warming potential (GWP) listed in the Intergovernmental Panel on Climate Change's Second Assessment Report (IPCC 1996b), to determine the relative heat-trapping ability of each gas.

The 2002 CAR—the analysis used by the Bush Administration in setting its intensity goal—and the analysis presented in this 2006 CAR use consistent analytical techniques. Baseline projections of energy-related CO_2 emissions are developed based on the latest edition of the AEO produced by EIA's NEMS model. Using the reference case scenario provided by EIA as a starting point, agencies with policy responsibility then adjust it to reflect their assessments of the additional impact of the policies and measures, as described above. For non-CO_2 GHGs and estimates of carbon sequestration, the inventory models described in Chapter 3 are used to project emissions based on economic activity from the AEO 2006 report.

U.S. GREENHOUSE GAS EMISSION ESTIMATES: 2000–2020

Projections for both the *Business As Usual* baseline and the *Full Implementation of Climate Programs and Measures* scenario are presented in Table 5-2 for the years 2012 and 2020, along with historical inventory data for the years 2000, 2002, and 2004. The projections of U.S. GHG emissions described here reflect estimates of GHG emissions considering national trends in population growth, long-term economic growth potential, historical rates of technology improvement, normal weather patterns, and reductions due to implemented policies and measures.

The total projected levels of U.S. greenhouse gas emissions are tallied by combining the CO_2 contributions of energy and nonenergy activities with the non-CO_2 greenhouse gases (which include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons

TABLE 5-2 **Historical and Projected U.S. Greenhouse Gas Emissions From All Sources** (Tg CO_2 Eq.)

U.S. GHG emissions from energy consumption and other anthropogenic sources are projected to grow from historic levels, although emissions projected with the *Full Implementation of Climate Programs and Measures* are lower than under the *Business As Usual* baseline.

GREENHOUSE GASES	HISTORICAL GHG EMISSIONS			PROJECTED GHG EMISSIONS			
	Business As Usual			Business As Usual		Full Implementation of Climate Programs and Measures[7]	
	2000[1]	2002[1]	2004[1]	2012[2]	2020	2012[2]	2020
Energy-Related CO_2[3]	5,534	5,502	5,657	6,318	6,931	6,060	6,447
Nonenergy CO_2[4]	331	314	331	361	396	361	396
Methane	567	560	557	621	667	599	621
Nitrous Oxide	416	407	387	383	399	380	397
High GWP Gases	135	133	143	434	622	312	417
Adjustments[5]	0	0	0	-3	52	-3	52
Total Gross Emissions	**6,982**	**6,916**	**7,074**	**8,115**	**9,067**	**7,709**	**8,330**
Sinks[6]	-760	-769	-780	-776	-675	-806	-709
Total Net Emissions	**6,223**	**6,147**	**6,294**	**7,340**	**8,392**	**6,903**	**7,621**
GROSS GHG INTENSITY							
GDP (billions of 2000 dollars)		$10,075		$13,793		$13,793	
Gross GHG Intensity		686		588		559	
2002–12 Gross GHG Intensity Reduction				-14.3%		-18.6%	

Notes:
[1] Historical emissions and sinks data are from U.S. EPA/OAP 2006c. Bunker fuels and biomass combustion are not included in inventory calculations.
[2] 2012 data are interpolated when specific data are unavailable.
[3] Energy-related CO_2 projections are calculated from U.S. DOE/EIA 2006a CO_2, with any CO_2 from nonenergy sources removed.
[4] Nonenergy CO_2 includes emissions from nonenergy fuel use and other industrial emission sources.
[5] Adjustments include international bunker fuels and emissions in U.S. territories.
[6] Sinks projections are extrapolated from U.S. EPA/OAP 2006c, with programs and measures projections from the U.S. Department of Agriculture.
[7] Programs and measures reductions for 2002 are presented in Chapter 4, but are not shown in this table because historical data are used to calculate the GHG intensity in 2002. Programs and measures reductions shown in this table are net of 2002 reductions for the purpose of calculating the reduction in emissions intensity from the initial implementation of the President's policy in 2002.

(PFCs), and sulfur hexafluoride (SF_6)), and then aggregating these using equivalence factors. Because some types of GHG emissions cannot be attributed to a particular economic sector, the totals are reported in aggregate.

U.S. GHG emissions from energy consumption, industrial and agricultural activities, and other anthropogenic sources continue to grow from 2002 levels as shown in Table 5-2. Gross emissions are projected to rise under the impetus of population and economic growth. Under the *Business As Usual* path, total gross U.S. GHG emissions would be expected to rise 30 percent between 2000 and 2020. However, in the *Full Implementation of Climate Programs and Measures* case, emissions are projected to rise from 6,982 Tg CO_2 Eq. in 2000 to 8,330 Tg CO_2 Eq. in 2020, a growth of 19 percent. Increased efforts to use cleaner fuels, more efficient technologies, and better management methods for agriculture, forestry, mines, and landfills are projected to keep the growth of GHG emissions below the concurrent growth of the U.S. economy. Moreover, emissions of some non-CO_2 greenhouse gases—e.g., methane and industrial gases associated with the production of aluminum and HCFC-22—have declined from 1990 levels and are projected to remain below 1990 levels out through 2020.

The projected emission levels with full programs and measures for the year 2020 are lower than the levels projected for the same year in the 2002 CAR. Conversely, the actual level of net emissions reported for 2000 is higher than the projected value in the 2002 CAR, mainly due to a revision of the available sinks. The sections that follow present more detailed projections of specific categories of total U.S. GHG emissions.

CO_2 Emissions

Energy CO_2 Emissions

From 2000 to 2020, total CO_2 emissions—as calculated with *Full Implementation of Climate Programs and Measures*—are projected to increase by 17 percent to an absolute level of 6,843 Tg CO_2. The estimated level of U.S. CO_2 emissions from fossil fuel combustion for the year 2020 is 6,447 Tg CO_2. These rising absolute levels of CO_2 emissions occur against a background of growing population and GDP.

Nonenergy CO_2 Emissions

Nonenergy sources of CO_2 emissions include natural gas production and processing, cement production, and waste handling and combustion. These CO_2 emissions are subject to increasing voluntary control, as U.S. firms use recapture technologies to reduce their emission levels. Because the underlying sources are so varied, there is no clear projection method available other than historical extrapolation. These nonenergy CO_2 emissions are projected to grow by 1 percent annually, from 331 Tg CO_2 in 2000 to 396 Tg CO_2 in 2020. The total nonenergy CO_2 emission estimates in this 2006 CAR are approximately two and a half times higher than in the 2002 CAR. This is due to the inclusion of significantly more nonenergy sources of CO_2 emissions.[7]

Non-CO_2 Greenhouse Gas Emissions

Emissions other than CO_2 include (1) CH_4 emissions from natural gas production and transmission, coal mine operation, landfills, and livestock operations; (2) N_2O emissions from agriculture and, to a lesser degree, transportation; and (3) HFC, PFC, and SF_6 gases from industrial activities and, in some cases, the life cycles of the resulting products.

Methane

With full programs and measures, total CH_4 emissions are estimated to increase from 567 Tg CO_2 Eq. in 2000 to 621 Tg CO_2 Eq. in 2020 (U.S. EPA/OAP 2006a), primarily due to increases in natural gas usage. The projection of total CH_4 emissions presented in this report is lower than that reported in the 2002 CAR in absolute terms. This is primarily due to an improved inventory accounting model for the landfill sector, which substantially lowered projected emissions from the sector.

Nitrous Oxide

N_2O emissions are expected to decline from 416 Tg CO_2 Eq. in 2000 to 397 Tg CO_2 Eq. in 2020. The largest single source of these emissions is agricultural soils. Emissions of N_2O from transportation are also expected to decrease over this period (U.S. EPA/OAP 2006b).

HFCs, PFCs, and SF_6

Emissions of HFCs, PFCs, and SF_6 are projected to rise from 135 Tg CO_2 Eq. in 2000 to 417 Tg CO_2 Eq. in 2020 (U.S. EPA/OAP 2006b). This increase stems largely from the use of HFCs as replacements for ozone-depleting substances. Growth in the use of HFCs will allow rapid phase-out of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons in a number of important applications where other alternatives are not available.

HFCs are expected to be selected for applications where they provide superior technical reliability or safety (low toxicity and flammability) performance. In many cases, HFCs provide equal or better energy efficiency compared to other available alternatives. Moreover, their acceptance in the market will reduce long-term net environmental impacts, because HFCs are expected to replace a significant portion of past and current demand for CFCs and HCFCs in insulating foams, refrigeration and air-conditioning, propellants used in metered dose inhalers, and other applications. Emissions of HFCs, PFCs, and SF_6 from all other industrial sources are expected to be reduced significantly below 1990 levels, despite high growth rates of manufacturing in some sectors.

[7] Since the 2002 CAR, the following CO_2 sources have been added to the U.S. inventory: nonenergy use of fuels, iron and steel production, ammonia production and urea application, petrochemical production, titanium dioxide production, phosphoric acid production, and ferroalloys.

Carbon Sequestration

U.S. forests and agricultural soils account for a significant removal of CO_2 from the atmosphere, representing 11 percent of total gross U.S. CO_2 emissions in 2000. This net removal—or sequestration—is related to a continuation of trends in land use and land management observed throughout the 1990s in the forestry and agriculture sectors, including the reforestation and regeneration of previously cleared forests and expanded use of no-till and reduced-tillage systems in agriculture.

While significant in quantity, the carbon sequestration that occurred in U.S. forests and agricultural soils prior to 2000 occurred in the absence of government incentives to sequester carbon. Since 2000, the U.S. government has implemented a number of innovations in its farm sector conservation programs to encourage private landowners to voluntarily adopt land uses and management practices that sequester additional carbon in forest systems and agricultural soils. Examples include a program to plant 203,250 hectares (500,000 acres) of bottomland hardwood forest (primarily in the Mississippi River Valley) and revised ranking criteria for prioritizing lands offered for enrollment in USDA's Environmental Quality Incentives Program and Conservation Reserve Program. These revised criteria allow federal program managers to give additional weight to bids that include the implementation of activities and/or practices that sequester carbon.

Table 5-2 shows both recent historical data and projections for 2012 and 2020 for annual carbon sequestration (i.e., sinks) in U.S. forests and agricultural soils.[8] Sequestration associated with forests includes carbon stored in the forest ecosystem, wood products in use, and wood products in landfills. Annual carbon sequestration due to innovative farm conservation programs (e.g., encouraging landowners to adopt carbon-sequestering land uses and/or management practices) is projected to increase by 2020, according to USDA estimates.

KEY UNCERTAINTIES AFFECTING PROJECTED GREENHOUSE GAS EMISSIONS

Any projection of future emissions is subject to considerable uncertainty. In the short term (less than 5 years), the key factors that can increase or decrease estimated net emissions include unexpected changes in retail energy prices, shifts in the competitive relationship between natural gas and coal in electricity generation markets, changes in economic growth, abnormal winter or summer temperatures, and imperfect forecasting methods. Additional factors may influence emission rates over the longer term, notably technology developments, shifts in the composition of economic activity, and changes in government policies.

Technology Development

Forecasts of net U.S. emissions of GHGs take into consideration likely improvements in technology over time. For example, technology-based energy-efficiency gains, which have contributed to reductions in U.S. energy intensity for more than 30 years, are expected to continue. However, while long-term trends in technology are often predictable, the specific areas in which significant technology improvements will occur and the specific new technologies that will become dominant in commercial markets are highly uncertain, especially over the long term.

Unexpected scientific and technical breakthroughs can cause changes in economic activities, with dramatic effects on patterns of energy production and use. Such breakthroughs could enable the United States to considerably reduce future GHG emissions. While U.S. government and private support of research and development efforts can accelerate the rate of technology change, the effect of such support on specific technology developments is unpredictable.

The AEO 2006 *Business As Usual* baseline referenced in this report assumes continuing improvement of energy-consuming and -producing technologies, consistent with historical trends. In the AEO 2006 high technology growth case, energy use in 2020 is projected to be 5 percent lower than in the reference case, while CO_2 emissions are projected to be 5 percent (or 385 Tg) lower than in the reference case.

Regulatory or Statutory Changes

The current forecast of U.S. GHG emissions does not include the effects of any legislative or regulatory action that was not finalized before October 31, 2005. Consequently, the forecast does not include any increase in the stringency of equipment efficiency standards, even though existing law requires DOE to periodically strengthen its existing standards and issue new standards for other products. Similarly, the forecast does not assume any future increase in new building or auto fuel economy standards, even though such increases are either required by law or under consideration in various states. For example, while the AEO 2006 includes the CAFE standards for light trucks covering 2005–07 and finalized in 2003, the more recent standards covering 2008–11 were not finalized in time to be incorporated.

Energy Prices

The relationship between energy prices and emissions is complex. Lower energy prices generally reduce the incentive for energy conservation and tend to encourage increased energy use and related emissions. However, a reduction in the price of natural gas relative to other fuels could encourage fuel switching that could, in turn, reduce carbon emissions. Alternatively,

[8] The projections for carbon sequestration are lower than the corresponding projections in the 2002 CAR due to revised inventory methods. An explanation of the revision has been provided to the UNFCCC in the 2002 edition of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA/OAP 2002), available at <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2002.html>.

coal could become more competitive vis-à-vis natural gas, which could increase emissions from the power sector.

The AEO 2006 projections reflect a shift in oil market assumptions, with projected oil prices substantially higher than in previous editions (U.S. DOE/EIA 2006a). However energy and oil price projections are subject to significant uncertainty. Decreases in delivered energy prices could result from increased competition in the electric utility sector or improved technology. On the other hand, energy price increases could result from the faster than expected depletion of oil and gas resources, or from political or other disruptions in oil-producing countries.

Economic Growth

Economic growth increases the future demand for energy services, such as vehicle miles traveled, amount of lighted and ventilated space, and process heat used in industrial production. However, growth also stimulates capital investment and reduces the average age of the capital stock, increasing its average energy efficiency. The energy-service demand and energy-efficiency effects of economic growth work in opposing directions. However, the effect on service demand is the stronger of the two, so that levels of primary energy use are positively correlated with the size of the economy.

In addition to the reference case cited previously, the AEO 2006 provides high and low economic growth cases. The high-growth case raises the GDP growth rate by 0.5 percentage points to 3.5 percent, while the low-growth case reduces the GDP growth rate by 0.6 percentage points to 2.4 percent.

- In the high-growth case, 2020 energy use is 5 percent higher than in the reference case. By 2020, carbon emissions from energy use are 423 Tg CO_2 (6.1 percent) greater than in the reference case.
- In the low-growth case, 2020 energy use is 6 percent lower than in the reference case. By 2020, carbon emissions from energy use are 399 Tg CO_2 (5.8 percent) lower than in the reference case.

Weather

Energy use for heating and cooling is directly responsive to weather variation. The AEO forecast of CO_2 emissions assumes 30-year average values for population-weighted heating and cooling degree-days. Unlike other sources of uncertainty, for which deviations between assumed and actual trends may follow a persistent course over time, the effect of weather on energy use and emissions in any particular year is largely independent from year to year.

6 Vulnerability Assessment, Climate Change Impacts, and Adaptation Measures

The United States is involved in a wide array of climate assessments, research, and other activities at the local, regional, national, and international levels to increase understanding of impacts and vulnerability needed to initiate effective adaptation measures. These activities range from assessments of adaptation options for a specific sectoral impact in one locale to the modeling of potential impacts worldwide. They inform decision-making processes at all levels and help to increase societal resilience to climate changes. Many of the most successful U.S. programs are demand-driven—they generate research or spur activities in response to the needs and priorities identified by decision makers to address current and near-term risks and opportunities.

The 2002 *U.S. Climate Action Report* (2002 CAR) highlighted findings from the National Assessment of climate change impacts on the United States (NAST 2000), and those of the Intergovernmental Panel on Climate Change (IPCC 2001a, b). The United States continues to use a range of peer-reviewed scientific outputs to inform decision making with regard to climate impacts, spanning domestic scientific articles and assessments to international assessments, such as those of the IPCC.

Since the release of the 2002 CAR, and as described in the *Strategic Plan of the U.S. Climate Change Science Program* (CCSP and SGCR 2003a), the U.S. government has undertaken an ambitious suite of focused assessments addressing high-priority research questions. This open, transparent approach communicates scientific analyses to the public via a set of 21 synthesis and assessment products developed by the U.S. Climate Change Science Program (CCSP). These products consider, evaluate, and summarize the current state of understanding in critical areas related to climate change, its ongoing and potential impacts, and options for responding to these changes. This material is intended for use by a diverse group of decision makers, stakeholders, communicators (e.g., the media), and scientists. The material addresses the Nation's need for sound scientific information that can lead to a better understanding of climate change impacts and vulnerabilities, as well improved design and implementation of adaptation measures. As with previous CCSP outputs, the synthesis and assessment products are reviewed by government and non-government scientists, U.S. government officials, stakeholders, and the general public. These products build on and integrate cutting-edge research and application activities, advanced over the years by the interagency research efforts in climate and global change.[1]

The synthesis and assessment products highlighted in this chapter will provide analyses of ongoing and potential impacts of climate variability and change, adaptability of key systems, and measures that may be taken to reduce vulnerability. Although many of these products are currently under development, the United States also has participated in a number of international climate change assessments that include consideration of

[1] More information about CCSP and the synthesis and assessment products may be found in Chapter 8 and at <www.climatescience.gov>.

BOX 6-1 U.S. Participation in International Impact Assessments

Since the *2002 CAR*, the United States has participated in two significant international assessments that address projected impacts of climate change on the United States—although within the larger context of the North American and Arctic regions. In the Arctic Climate Impact Assessment (AC and IASC 2004), the authors found that:

- Arctic climate is now warming rapidly, and much larger changes are projected.
- Arctic warming and its consequences have worldwide implications.
- Arctic vegetation zones are very likely to shift, causing wide-ranging impacts.
- Animal species' diversity, ranges, and distribution will change.
- Many coastal communities and facilities face increasing exposure to storms.
- Reduced sea ice is very likely to increase marine transport and access to resources.
- Thawing ground will disrupt transportation, buildings, and other infrastructure.
- Indigenous communities are facing major economic and cultural impacts.
- Elevated ultraviolet radiation levels will affect people, plants, and animals.
- Multiple influences interact to cause impacts to people and ecosystems.

Current information on impacts on polar regions and on the North American region can also be found in the Working Group II Contribution to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report: Climate Change Impacts, Adaptation and Vulnerability. The United States is an active participant in the creation of this report, which will be completed in November 2007. The most recent findings of the IPCC are available at <http://www.ipcc.ch/>.

projected impacts and adaptation of relevance to the Nation (see Box 6-1).In addition, this chapter focuses on activities the United States is undertaking to assess and respond to specific types of impacts and vulnerability, in accordance with Article 12 of the U.N. Framework Convention on Climate Change. It also highlights ongoing U.S. efforts that are generating new insights into the potential impacts of climate change on key physical and biological processes (e.g., snowpack changes, streamflow, drought, extreme events, biodiversity) and changing resilience and vulnerability in a range of socioeconomic sectors (e.g., energy, forestry, agriculture, coastal systems, human health, and transportation). It provides an overview of the current U.S. government approach toward characterizing and reducing uncertainty associated with specific climate-related issues and providing practical scientific information and tools to decision makers via CCSP and other mechanisms. Often these activities take place within broader activities to improve sectoral risk management within the context of many changing social, economic, and environmental factors. Many of these activities are leading to demonstrable reductions in socioeconomic and environmental vulnerability to climate variability and change.

DEVELOPING RESILIENT SOCIETIES AND ECONOMIES

The ultimate goal of adaptation is to develop resilient societies and economies that have the knowledge and capacity to address both the challenges and the opportunities presented by changing climatic conditions. Climate change will alter patterns of climate variability in unknown ways. Resilience is a matter of reducing present vulnerability as well as minimizing the risk of future vulnerability to climate events. Efforts to help sensitive populations adapt to current climate variability have shown that socioeconomic, environmental, and climatic stresses are all connected. Future changes in these conditions could substantially alter the environment in which adaptation must take place. The full range of likely future stresses must be considered. To be sustainable, adaptation efforts must consider options that build resilience to these stresses (Goklany 1995, 2007).

Decision makers and planners in such climate-dependent sectors as agriculture and water generally consider historical patterns of climate variability and extreme events, particularly those that have occurred relatively recently. These include considerations of variations at short time scales (e.g., seasonal and annual variations). Relatively few decision makers, however, consider variations in climate that occur on longer time scales (e.g., decades to a century). Moreover, decision makers do not typically consider how potential climate change could cause patterns of climate variability to differ from historical trends. Although scenario-based assessments regarding the future do not always agree on the type or direction of change that might occur, and these disagreements often increase at smaller geographical scales, global and regional climate models provide a range of projections that can be helpful in communicating climate risks to regional decision makers.

A key component in building resilience into human and natural systems is to expand scientific understanding of the nature and implications of climate variability and change across sectors, often within a place-specific framework that considers the socioeconomic and institutional capacities and decision-making practices. Lessons from early research investments intended to increase understanding of the human and natural sources of vulnerability to climate variability and change have profoundly influenced the approach of the current U.S. research program. As called for in the CCSP strategic plan, research partnerships have been initiated and sustained in some regions to involve decision makers in the process of identifying knowledge gaps of the highest relevance to their decision processes (CCSP and SGCR 2003a). These partnerships have also explored mechanisms for improving the utility and flow of knowledge from the research community to those who can use and benefit from it.

Box 6-2 presents a cross-section of the types of programs being carried out by the United States at the international, federal, state, and local levels to assess impacts of climate change and reduce vulnerability. This list is not comprehensive; rather it is a small sample of the relevant activities being carried out on a variety of scales in the United States. A continuing goal is a coherent program that allows synergies among these many and varied programs.

SECTOR-SPECIFIC U.S. ADAPTATION ACTIVITIES

The sector- and region-specific projects in this section illustrate the variety and scale of adaptation methods utilized within the United States. They represent only a small sample of key areas of investigation the United States has undertaken in its extensive portfolio of past and current adaptation activities.

Water Resources

Changes in atmospheric, surface, and subsurface water storage and flow have been observed over the past several decades in the United States (Groisman et al. 2004). Whether due to anthropogenic or natural causes, these changes have significant implications for the provision of adequate water supply for human consumption, agriculture, energy production, industrial uses, and other needs. While population growth, pollution, and industrial development add stresses to the water supply (U.S. DOI 2003), climate variations and change may significantly exacerbate water supply issues.

For example, despite increases in winter precipitation, in many places a large percentage of the traditionally snow-covered areas of the northwestern United States has experienced a decline in spring snowpack, especially since the middle of the 20th century (Mote et al. 2005). The largest decreases have occurred at lower elevations where snowpack is most sensitive to temperature and in regions where

BOX 6-2 Sample U.S. Climate Vulnerability and Change Research Programs and Activities

The U.S. government supports several programs and activities that are working to assess the impacts of climate change and reduce vulnerability across sectors. Following is a sample cross-section of the types of programs being carried out at all levels to build resilience into human and natural systems.

International Programs and Activities

NASA and USAID Regional Hubs
The National Aeronautics and Space Administration (NASA) and the U.S. Agency for International Development (USAID) are developing regional hubs around the world to apply remotely sensed information to development assistance. Based on the successful SERVIR hub in Central America, this activity will link available data streams to new applications, develop tools, and build local human and institutional capacity to use this information. These systems will support decision making in a number of areas, including climate change, land management, urban planning, food security, agriculture, and disaster mitigation.

USAID Climate Change Program
Often in partnership with other agencies, USAID leads a number of activities to help build developing country capacity to understand climate change and adapt to its impacts. Its Climate Change Program conducts projects to test methodologies to insert climate information in mainstream development project planning. The projects emphasize stakeholder participation. For example, USAID:

- worked with farmers in Mali, planting crop varieties that are better suited to a hotter climate;
- helped local stakeholders in South Africa identify water demand management and infrastructure requirements as climate changes;
- addressed flooding concerns with coastal residents, businesses, and planning officials in Honduras; and
- helped fishermen and farmers in Thailand determine how to build resilience to warming temperatures and more variable rains.

Lessons learned from these projects informed the development of an adaptation guidance manual, which is being applied in additional projects in cooperation with USAID missions around the world. The manual will be disseminated to USAID missions and other development partners to ensure the methods and tools are used broadly.

Local to National Programs and Activities

NASA Applied Sciences Program
This program benchmarks practical uses of NASA-sponsored observations from Earth observation systems and predictions from Earth science models. NASA implements projects that carry forth this mission through partnerships with public, private, and academic organizations developing innovative approaches for using Earth system science information to provide decision support that can be adapted in applications worldwide. The program focuses on applications of national priority to expand and accelerate the use of knowledge, science, and technologies resulting from the NASA goal of improving predictions in the areas of weather, climate, and natural hazards.[2]

EPA Global Change Research Program
The primary emphasis of this U.S. Environmental Protection Agency (EPA) assessment-oriented program is understanding the potential consequences of climate variability and change on human health, ecosystems, and socioeconomic systems in the United States. This work entails (1) improving the scientific basis for evaluating the effects of global change in the context of other stressors and human dimensions (as humans are catalysts of and respond to global change), (2) conducting assessments of the risks and opportunities presented by global change, and (3) assessing adaptation options to improve society's ability to effectively respond to those risks and opportunities as they emerge. EPA's intramural assessment program has four areas of emphasis: (1) human health, (2) air quality, (3) water quality, and (4) ecosystem health. In an attempt to capitalize on expertise in the academic community, a significant portion of the program's resources are dedicated to extramural research grants administered through EPA's STAR (Science to Achieve Results) grants program, which supports science related to assessments of consequences of global change and human dimensions research. [3]

[2] See <http://science.hq.nasa.gov/earth-sun/aplications/index.html>.
[3] See <http://cfpub.epa.gov/gcrp/about_ov.cfm>.

BOX 6-2 (Continued) **Sample U.S. Climate Vulnerability and Change Research Programs and Activities**

NSF Decision Making Under Uncertainty Centers
These National Science Foundation (NSF) centers are comprised of five interdisciplinary research teams studying important aspects of problems associated with understanding climate-related decisions under uncertainty. The increased knowledge generated by recent scientific research on the causes and consequences of climate change and variability has led to a growing need to better understand how decision makers choose among alternative courses of action. These teams are expected to produce new insights of interest to the academic community, generate significant educational benefits, and develop new tools that will benefit decision makers and a range of stakeholders. Research centers are located at Arizona State, Carnegie-Mellon, and Columbia universities. Other interdisciplinary teams are conducting research at the University of Colorado at Boulder and Rand Corporation in Santa Monica, California.

National Water and Climate Center
Administered by the U.S. Department of Agriculture's Natural Resources Conservation Service, the National Water and Climate Center (NWCC) focuses on providing leadership in a partnership effort to help people conserve, improve, and sustain their natural resources and environment. NWCC's mission is to lead the development and transfer of water and climate information and technology that support natural resource conservation through natural resource planning support, data acquisition and management, technology innovation and transfer, and partnerships and joint ventures.[4]

Regional Program

Regional Integrated Sciences and Assessments (RISA) Program
The National Oceanic and Atmospheric Administration's (NOAA's) RISA program supports research that addresses complex climate-sensitive regional issues of concern to decision makers and policy planners. RISA research team members are primarily based at universities, though some are based at government research facilities, nonprofit organizations, and private-sector entities. Research areas include the fisheries, water, wildfire, and agriculture sectors, coastal restoration, and climate-sensitive public health issues.[5]

State Program

California Climate Change Center
The center investigates the range of possible changes to California's climate and the likelihood and rate of progression of such changes. Using the results of this work, the center is assessing the potential future economic and ecological consequences of climate change for California, and is examining a range of impacts and adaptation options concerning, e.g., agriculture and water resources, as well as mitigation strategies. The center manages a robust research program with a dynamic community of California researchers from various scientific disciplines and a worldwide network of peers collaborating on climate change issues of interest to California.[6]

Local Program

King County Global Warming Initiative
Washington State's King County is pursuing aggressive strategies to reduce and adapt to global warming in each of the following areas: land use, public transportation, innovative environmental management, and development of clean energy technologies. The county is one of several jurisdictions that are accounting for climate change in their short- and long-term infrastructural planning. Specific actions being taken by King County that account explicitly for climate change include developing a flood plan and proposed major upgrades in its 119 miles of levees on local rivers, as well as constructing a $28 million reclaimed water system to help address expected water shortages.[7]

winter temperatures are mild, especially in the Cascade Mountains and northern California. Substantial declines in snow-water equivalent have been observed in lower elevations of the Pacific Northwest (Mote 2003), along with a significant reduction in spring snow cover over the region during the last half century (Groisman et al. 2004), and about a one-week advance since the mid-1960s in the timing of peak snowmelt in northern Alaska (Stone et al. 2002). The peak of streamflow in the Pacific Northwest and New England, in basins dominated by snowmelt, has typically advanced by 1–2 weeks (Groisman et al. 2004; Hodgkins et al. 2003), thereby providing less river runoff during the late spring and summer.

Another example of potential changes is the severe and extreme drought that is a recurring feature across much of the United States. Research suggests that a broad array of physical mechanisms contributes to droughts, from internal atmospheric variability on the shortest time scales, to interactions with oceans and land surface at seasonal-to-decadal and longer time scales. Among recent scientific studies is one suggesting that drought conditions in the 1998–2002 time frame over North America, parts of southern Europe, and southwest Asia were linked to particular ocean conditions (Hoerling and Kumar 2003). Cold sea-surface temperatures in the eastern tropical Pacific and unprecedented warm sea-surface conditions in the western tropical Pacific and Indian Oceans worked synergistically to cause widespread drying in the mid-latitudes. This synergy suggests an increased risk for severe and synchronized drying of Northern Hemisphere mid-latitudes if similar oceanic conditions occur in the future. The warmer temperatures projected with rising concentrations of greenhouse gases are expected to exacerbate present risks of drought in the United States by increasing the rate of evaporation (Gleick 2000). However, the effects of drought and low soil moisture on vegetation, including crops, may be offset by higher CO_2 levels—or at least partly offset for a period of time (e.g., Triggs et al. 2004; Nelson et al. 2004).

Regional Integrated Sciences and Assessments

Federally funded researchers are working with water and ecosystem managers as

[4] See <http://www.wcc.nrcs.usda.gov/>.
[5] See <http://www.climate.noaa.gov/cpo_pa/risa/>.
[6] See <http://www.climatechange.ca.gov/research/index. html>.
[7] See <http://www.metrokc.gov/globalwarming/default.sapx>.

new insights and techniques become available, allowing incorporation of scientific data and information into near- and long-term planning. NOAA's Climate Program Office funds eight programs designed to provide the Nation with experience-based knowledge about how to provide climate services (see Box 6-1).[8] Called Regional Integrated Sciences and Assessments (RISAs), these programs are an important element of CCSP's efforts to support decision making on climate-related issues. Following are some sample RISA programs.

Climate Impacts Group—The University of Washington's Climate Impacts Group (CIG) is using emerging knowledge to help inform decision making related to changing hydroclimatic conditions in the Pacific Northwest. CIG is utilizing its hydrologic modeling and prediction capabilities to evaluate water resource issues, including the consequences of alternative water and hydroelectric power management strategies for salmon restoration efforts, and the consequences of changing water demands and changes in land cover for regional water resources.[9]

Western Water Assessment—The Western Water Assessment (WWA) is examining the interplay between changing hydrologic and climatic conditions, and the complex array of intrastate, interstate, and international water agreements in the Colorado River Basin. Recent analyses indicate that current "assumptions about planning in the Colorado basin [are not] borne out by the climate record [of natural variability] and by projections of change" (Pulwarty et al. 2005). Working with water managers, WWA researchers have analyzed how interannual-to-multidecadal climate variability affects critical water issues and what climate information can be used in the resource management decision process to meet multiple and expanding water uses in the basin.[10] Using multidisciplinary teams of experts in climate, water, law, and economics, WWA provides information (usually in the form of climate forecasts and regional vulnerability assessments) designed to assist water-resource decision makers, such as those responsible for managing Denver's water supply.

Climate Assessment for the Southwest—A RISA based at the University of Arizona, titled the Climate Assessment for the Southwest,[11] is developing and using new information on drought to increase societal resilience to this recurrent phenomenon. The impacts of U.S. drought during the last 5–7 years have included sustained and extensive economic losses, significantly reduced reservoir levels, water emergencies, and widespread and severe wildfires.

Creating a more drought-resilient society requires a fundamental shift from crisis management to risk management. Investigators studying the impacts of drought are researching the historical record, evolving demographics and population growth, water law, and ecosystem management. For example, they are working to develop methods to utilize seasonal climate and streamflow forecasts more effectively to mitigate the impact of drought on water supplies. This type of knowledge is expected to become even more valuable in the coming decades, if climate model projections of increasing aridity in continental interiors prove accurate.

National Integrated Drought Information System

The sustained drought in parts of the U.S. West has exposed critical vulnerabilities and has revealed the effects of multiple stresses on institutions designed under different climatological circumstances. This experience has prompted advances in preparedness and a national-scale response through the development of a National Integrated Drought Information System (NIDIS) (WGA 2004). NIDIS is designed as a user-based drought information system that assesses potential drought indicators and impacts to provide tools for anticipating, preparing for, and mitigating the effects of drought. U.S. government services and research aim to provide the scientific knowledge needed for U.S. public and private sectors to anticipate, track, assess, and respond to drought threats at regional and local levels.[12]

New York City Task Force on Climate Change

As in the U.S. West, water issues are of concern in the eastern half of the country as well. The New York City Department of Environmental Protection, which provides water for 9 million people in the New York metropolitan region, has created a Task Force on Climate Change that is comprehensively addressing climate variability and change (Rosenzweig et al. 2007). The task force has developed a robust, dynamic, scenario framework for the region; built a set of adaptation assessment steps that characterizes potential adaptations as operations/management, infrastructure, or policy; and identified key vulnerabilities, such as sea level rise for sewer and wastewater treatment systems and the need for integrated modeling of upstate regions of water supply and reservoirs.

Ecosystems

Climate is an important factor influencing the distribution, structure, function, and services of ecosystems. Ongoing climate changes are interacting with other environmental changes to affect biodiversity and the future condition of ecosystems (e.g., IPCC 2001b; McCarty 2001; Parmesan and Yohe 2003). Significant climate change would affect many U.S. ecosystems, including wetlands, forests, grasslands, rivers, and lakes (NRC 2001). The extent to which ecosystem conditions will be affected will depend on the magnitude of climate change, the degree of sensitivity of the ecosystem and nonclimate pressures on biodiversity to that change, the availability of adaptation options for effective ecosystem management, and the willingness to deploy those options.

[8] See <http://www.climate.noaa.gov/cpo_pa/risa/>.
[9] See <http://www.cses.washington.edu/cig/res/hwr/hwr.shtml>.
[10] See <http://wwa.colorado.edu/about/>.
[11] See <http://www.ispe.arizona.edu/climas>.
[12] For example, see <http://www.drought.noaa.gov/>.

Adaptation Strategies and Options

CCSP addresses management strategies for facilitating ecosystem adaptation to climate variability and change. The goal of these adaptation strategies is to reduce the risk of adverse outcomes through activities that increase the resilience of ecological systems to climate change, and to take advantage of positive outcomes (Turner et al. 2003; Tompkins and Adger 2004; Scheffer et al. 2001). Because changes in the climate system are likely to persist into the future regardless of emissions mitigation, adaptation is an essential response for future protection of climate-sensitive ecosystems.

Adaptation options for enhancing ecosystem resilience include changes in processes, practices, or structures to reduce anticipated damages or enhance beneficial responses associated with climate variability and change. In some cases, opportunities for adaptation offer stakeholders multiple benefit outcomes, such as the addition of riparian buffer strips that, for example, manage pollution loadings from agricultural land into rivers or provide a protective barrier to increases in both pollution and sediment loadings that may be associated with future climate or other environmental change. Adaptation options also include measures that would reduce current vulnerabilities to ecosystems—e.g., loss of habitat and migratory corridors—by enhancing the productivity of current food and agricultural practices (Goklany 1995, 1998, 2007). Such options could reduce what is frequently considered to be an important threat to biodiversity, as well as conserve carbon stocks and sinks, but the potential for those systems to be affected by a changing climate needs to be taken into account as adaptation and mitigation options are evaluated.

A range of adaptation options is possible for many ecosystems, but a lack of information or resources may impede successful implementation. In some cases, managers may not have the knowledge or information they need to address climate change impacts. In other instances, managers may understand the issues and have the relevant information but lack resources to implement adaptation options. Furthermore, even with improvement in the knowledge and communication of available and emerging adaptation strategies, the feasibility and effectiveness of adaptation will depend on the adaptive capacity of the ecological system or social entity.

Thus, increasing adaptive capacity will require information and tools that aid in (1) understanding the combined effects on ecosystems of climate changes and nonclimate stressors, and consequent implications for achieving specific management goals; (2) applying existing management options or developing new adaptation approaches that reduce the risk of negative outcomes; and (3) understanding the opportunities and barriers that affect successful implementation of management strategies to address climate change impacts.

CCSP's Ecosystem Adaptation Work

One example of work by CCSP in improving the adaptive capacity of ecosystems relates to understanding climate and wildfire interactions on a regional scale for the western United States (Roads et al. 2005; Reinbold et al. 2004), development of long-lead forecasts for use by wildfire managers (Brown et al. 2003), and compilation of a comprehensive new western U.S. 21-year fire history to facilitate climate-based predictions of the potential severity of the fire season several months in advance (Westerling et al. 2003). The United States supports yearly regional meetings to prepare fire forecasts that integrate the complex pattern of fire potential anomalies, current and evolving climate conditions, fuel types, extended climate predictions, and disturbance factors, such as drought- or insect-induced forest mortality.[13]

Another example of CCSP's adaptation work related to managed ecosystems involves the agricultural sector. Building on assessments of the impacts of El Niño on particular crops, and interactions with farmers and extension agents, U.S. research scientists are contributing information and climate predictions tailored to the specific needs of farmers, enabling them to plan in advance seasons, or longer, to increase productivity and decrease exposure.[14] Methods are also currently being developed for limiting potential damages from global warming in irrigated and rain-fed cropping systems, while sustaining agricultural yields.

The polar and subpolar regions, another CCSP priority, have exhibited more rapid changes than the lower latitudes (AC and IASC 2004). The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) is the lead U.S. government laboratory for polar and subpolar expertise. CRREL research has examined the impacts of climate change on retreating Arctic sea ice to assist in defining the requirements for U.S. Coast Guard ice-breaking ships for the next 30 years. Satellite data show that the extent of Arctic sea ice has decreased by about 10 percent, and the upward-looking sonar data from U.S. Navy submarines between 1957 and 2000 show the average ice thickness has decreased by 33–42 percent.

State-of-the-art knowledge on ecosystem impacts, adaptation, and vulnerability will be addressed in three different CCSP synthesis and assessment products: S&A Product 4.2, *State-of-Knowledge of Thresholds of Change That Could Lead to Discontinuities in Some Ecosystems and Climate-Sensitive Resources*; S&A Product 4.3, *The Effects of Climate Change on Agriculture, Biodiversity, Land, and Water Resources*; and S&A Product 4.4, *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources.*

International Ecosystem Adaptation Activities

Internationally, the United States collaborates with developing country partners in a broad range of activities designed to better understand climate and its implications for development and to build resilience to climate variability and change. These activities

[13] For example, see <http://www.iawfonline.org/conferences.shtml>, <http://www.sftrforest.org>, <http://www.wildfirecolorado.org>, <http://www.stateforesters.org>.

[14] For example, see <http://www.agclimate.org/Development/apps/agClimate/controller/perl/agClimate.pl>.

include analyzing data from Earth observations, developing decision-support tools, and integrating climate information into development projects. For example, USAID and NOAA collaborate with developing country partners to operate the Famine Early Warning System Network (FEWS NET), which combines data from satellite observations with local meteorological, crop, and livelihood information to provide decision makers with early warnings of food security risks. FEWS NET operates in 21 countries and has been providing early warnings for 20 years. Similar programs are being developed to warn of risks of malaria, meningitis, and pests.

Public Health

Throughout the world, the prevalence of some diseases and other threats to human health depends largely on local climate. Given the complexity of the factors that influence human health, assessing health impacts related to climate change poses a difficult challenge (NRC 2001). The extent and nature of climate change impacts on human health vary by region, by relative sensitivity of population groups, by the extent and duration of exposure to climate change itself, and by society's ability to adapt to or cope with the change (Rose et al. 2001). The U.S. government has undertaken several initiatives to better understand and to develop and implement responses to these potential changes.

Centers for Disease Control and Prevention Research

A variety of efforts are underway in the United States to reduce negative health outcomes related to climate variability and change. For example, the Division of Environmental Hazards and Health Effects within the U.S. Department of Health and Human Services' Centers for Disease Control and Prevention (CDC) conducts intramural research to investigate morbidity and mortality associated with exposure to excessive heat. Also, renewed concern about emerging and re-emerging infectious diseases has prompted increased attention to a variety of diseases whose incidence would be affected by environmental change. CDC's Division of Vector-Borne Infectious Diseases is currently collaborating on studies to outline adaptation measures for vector-borne infectious diseases that may be affected by climate change. Its Guatemala field station is studying the impact that adverse climatological events, such as El Niño and Hurricane Gilbert, have had on the transmission dynamics of malaria and other diseases. These catastrophic events result in tremendous changes that can simultaneously create new vector habitat, reduce the levels of sanitation, and overwhelm the ability of public health systems to respond.

Global Change Research Program Assessments

EPA's Global Change Research Program is undertaking important work assessing the relationships between climate change and human health. This assessment work goes beyond basic epidemiological research to develop integrated health assessment frameworks that consider the effects of multiple stresses, their interactions, and human adaptive responses. Along with health sector assessments, conducted in conjunction with the U.S. Global Change Research Program's National Assessment process, the work includes research and assessment activities focused on the consequences of global change on weather-related morbidity and vector- and water-borne diseases. In addition, the results from the Global Change Research Program's air quality assessments will be used to evaluate health consequences.[15]

Decision-Support Tools

One example of a decision-support tool that has been developed to help reduce the negative effects of climate variability and change on human health is work on encephalitis viruses. The risk of infection from these viruses depends in part on temperature-related factors. Activities are underway that use climate forecasting at various spatial scales to alert local and state public health officials to changing risks of encephalitis infection. A risk model has been developed that characterizes climate factors related to encephalitis outbreaks (e.g., indicators for rainfall, runoff, and temperature) in California. The model demonstrates that mosquito abundance patterns and associated patterns of encephalitis risk vary spatially across the different biomes of California and show strong links to climate variations (Barker et al. 2003).

Another example of a decision-support tool is the *Excessive Heat Events Guidebook*, developed by EPA and other federal agencies responsible for addressing "excessive heat events" (EHEs) (U.S. EPA/OAP 2006a). The guidebook provides interested public health officials with information on risks and impacts from EHEs, including guidance on EHE forecasting and identification. It also provides a menu of notification and response actions to consider when developing or enhancing a local EHE program based in part upon a review of various EHE response programs.[16]

CCSP S&A Product 4.6, *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*, will provide a timely update to the 2000 Health Sector Assessment (Patz et al. 2000). This product will, in part, report on the potential human health effects of global environmental change, and the climate, socioeconomic, and environmental information that is needed to assess the cumulative risk to health in the United States from these effects. It will also inform adaptations in the provision of public health and health care interventions.

Coasts

Sea level is rising 2–3 millimeters (0.08–0.12 inches) per year along most of the U.S. coast (Zervas 2001). Accounting for local subsidence, coastal scientists are considering the possible impacts of a 1–3-foot rise in sea level over the next century (IPCC 2001a). Key concerns associated with these changes include land loss, increased flooding of low-lying coastal communities, coastal erosion, barrier island

[15] See <http://cfpub.epa.gov/gcrp/>.
[16] See <http://www.epa.gov/heatisland/about/heatguidebook.html>.

migration, vertical accretion of wetlands, and increased salinity of aquifers and estuaries, especially during droughts.

Approximately half the U.S. population—153 million people—lives in one of the 673 coastal counties; this number is expected to grow by 7 million by 2008 (U.S. DOC/NOAA 2004). Increases in coastal vulnerability are strongly affected by increasing coastal populations (Höppe and Pielke 2006), as well by as the effects of sea level rise and changes in the intensity and frequency of coastal storms. After a period of relatively light activity, the Atlantic basin has recently experienced an increase in hurricane activity, the cause of which is the subject of ongoing scientific debate (e.g., Webster et al. 2005; Hoyos et al. 2006; Kossin et al. 2007; Landsea et al. 2006). Concern over this increasing societal vulnerability is leading some insurance companies to increase rates or deny property coverage to communities along the Gulf and Atlantic coasts (Mills 2005). Due largely to improved warning systems, death and death rates from extreme weather events have generally declined since the beginning of the 20th century.

Reducing Vulnerability to Sea Level Rise

In recognition of significant potential impacts from climate change, the Federal Coastal Zone Management Act states: "Because global warming may result in a substantial sea-level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence (16 US Code § 1451)." Property owners and federal, state, and local governments are already starting to take measures to prepare for the consequences of rising sea level. Most coastal states are working with the U.S. Army Corps of Engineers to place sand onto their beaches to offset shore erosion. Property owners are elevating existing structures in many low-lying areas, which provide resilience to episodic storms as well as long-term change.

Shoreline erosion along estuaries has led many property owners to defend their property by erecting shore protection structures such as bulkheads, which eliminate the intertidal wetlands and beaches that would otherwise be found between the water and the dry land. 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 30–60 years (e.g. North Carolina Coastal Resources Commission). Concerned about the need to protect property rights, Maine, Rhode Island, 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 (IPCC 2001b).

Developing Data for Addressing Sea Level Rise

Many agencies and individuals are developing data that can provide insights regarding the implications of sea level rise. Following are some examples of these efforts:

- NASA, with its partner the French space agency, continues to provide climate-quality global sea level data every 10 days.
- The Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers, and several states are developing elevation data for floodplain management.
- NOAA and the U.S. Geological Survey (USGS) are developing Digital Elevation Models that use a common vertical reference frame for both topographic and bathymetric maps (Hess et al. 2004).
- Local governments and major coastal land conservancies are developing geographic information system land-use data for managing ecosystems and economic growth.
- The U.S. Fish and Wildlife Service is developing relevant wetlands data.
- NOAA's Coastal Change Analysis Program periodically provides a comprehensive assessment of land cover changes in the U.S. coastal zone.
- USGS collects high-resolution LIDAR elevation data for producing assessments of shoreline erosion and other coastal processes through its National Assessment of Coastal Change Hazards. FEMA has conducted similar analyses.
- USGS also evaluates the ability of wetlands to keep pace with rising relative sea level.
- EPA has been working with local governments to create county-scale maps that identify the areas likely to require shore protection as sea level rises.
- The New York City Department of Environmental Protection is analyzing the effects of current and future sea level rise on its coastal infrastructure (Rosenzweig et al. 2007).
- CCSP S&A Product 4.1, *Coastal Elevations and Sensitivity to Sea Level Rise*, will synthesize information from the ongoing mapping efforts by federal and non-federal researchers related to the implications of rising sea level.

Transportation

Transportation accounts for approximately one-quarter of total U.S. greenhouse gas emissions. Climate change will most likely have significant impacts on transportation infrastructure and operations (U.S. DOT 2006b). The safety and security of the national transportation infrastructure, as well as emergency and routine transportation operations, could also be affected (U.S. DOT 2006b). Examples of specific types of impacts include softening of asphalt roads, warping of railroad rails, decreased airplane "lift" in extremely hot air, and damage to roads and opening of shipping routes in polar regions (IPCC 2001b).

The United States is working to provide better information to decision makers across the transportation sector about what future climate variability and change could mean for existing and planned infrastructure and about the set of potential response strategies that might be implemented to adapt to future climate.

DOT Programs, Initiatives, and Studies

The Center for Climate Change and Environmental Forecasting is an initiative of the U.S. Department of Transportation

[17] See <www.dot.gov/climate>.

(DOT) dedicated to fostering awareness of the potential links between transportation and global climate change, and to formulating policy options to deal with the challenges posed by climate change and variability.[17] Several DOT programs are helping to curb greenhouse gas emissions and pollution from transportation, including the Automotive Fuel Economy Program, the Congestion Mitigation and Air Quality Improvement Program, and the Voluntary Airport Low Emissions Program. DOT research projects are investigating the potential impacts of climate variability and change on transportation infrastructure and its operation, and are providing guidance as to how transportation planners and decision makers may incorporate this information into transportation planning decisions to ensure a reliable and robust future transportation network.

DOT has partnered with the National Academies of Science/Transportation Research Board (TRB) to study strategies for the transportation system to adapt to potential impacts of climate change. The DOT/TRB study will reexamine the role of design standards for transportation infrastructure considering potential impacts from climate change, develop operational responses to potential climate change impacts, and review approaches to decision making under uncertainty.

A related DOT study is focusing on the central U.S. Gulf Coast. The region's unique transport modes and commercial significance add texture and interest to its transportation sector, while its unusual topography and geographic location make it particularly vulnerable to sea level rise and the threat of severe weather events. Results from this research will be reported in CCSP S&A Product 4.7, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure.*

Energy

Energy production and use are sensitive to changes in climate. For example, increasing temperatures will reduce consumption of energy for heating but will increase energy used for cooling buildings. The net effects of these changes on energy production, use, and utility bills will vary by region and by season (Hadley et al. 2006; Scott et al. 2005). There may be changes in energy consumed for other climate-sensitive processes, such as pumping water for irrigation in agriculture (Peart et al. 1995; IPCC 2001b). Depending on the magnitude of these possible energy consumption changes, it may be necessary to consider changes in energy supply or conservation practices to balance demand (Franco and Sanstad 2006; CEPA 2006).

Hydropower

To date, less research has been undertaken on how climate change may affect energy production. Hydropower generation is the energy source that is likely to be most directly affected by climate change because it is sensitive to the amount, timing, and geographic pattern of precipitation and temperature (IPCC 2001b). However, changes in precipitation are difficult to project at the regional scale, which means that climate change will affect hydropower either positively or negatively, depending on the region.

Renewable Energy

Some renewable sources of energy could be affected by climate change, although these changes are very difficult to predict. If climate change leads to increased cloudiness, solar energy production could be reduced. Wind energy production would be reduced if wind speeds rise above or fall below the acceptable operating range of the technology. Changes in growing conditions could affect biomass production—a transportation and power plant fuel source that is starting to receive more attention (IPCC 2001b). Climate change may also have complex effects on U.S. energy conditions through effects on global and hemispheric energy markets and policies.

Energy Infrastructure

Infrastructure for energy production, transmission, and distribution could be affected by climate change as well. For example, changes in the frequency and magnitudes of more extreme weather events, such as windstorms, ice storms, floods, tornadoes, and hail, and associated damages to the transmission systems of electric utilities may affect the rate of failure with attendant costs (IPCC 2001b). Power plant operations can be affected by the frequency and magnitude of extreme heat and cold waves. For example, intake water that is normally used to cool power plants may become warm enough during extreme heat events to compromise power plant operations, or ice storms may bring down transmission lines.

Energy Supply and Demand

Climate change effects on energy supply and demand will depend not only on climatic factors, but also on patterns of economic growth, land use, population growth and distribution, technological change, and social and cultural trends that shape individual and institutional actions (IPCC 2001b).

Prospects for Adaptation

Because of the lack of research to date, prospects for adaptation to climate change effects by energy providers, energy users, and society at large are speculative, although the potentials are considerable. Perhaps the greatest challenges could be in connection with possible increases in the intensity of extreme weather events and possible significant changes in regional water supply regimes. But adaptation prospects depend considerably on the availability of information about possible climate change effects to inform decisions about adaptive management, along with technological change in the longer term. Given that the current knowledge base is so limited, CCSP S&A Product 4.5, *Effects of Global Change on Energy Production and Use*, will summarize what is currently known about effects of climate change on energy production and use in the United States and will address needs for expanded research, through broad-based collaboration among federal and state governments, industry, nongovernmental institutions, and academia.

7 Financial Resources and Transfer of Technology

The international commercialization of technologies that mitigate greenhouse gas emissions, reduce air pollution, and enhance energy security in a context of economic growth is a central objective of U.S. climate and development policies.

A successful global response to climate change requires the participation of countries from all regions of the world. At the same time the United States is working to address climate change at home, we are working closely with and supporting partners around the world. U.S. policies are seeking to help developing countries to slow emissions growth in the near term and build capacity for longer-term efforts to ensure cleaner, sustainable development and progress toward a low-emissions economy.

The U.S. approach recognizes that progress will be best achieved by embedding climate goals in a broader agenda for developing countries—including the promotion of economic growth, reduction of poverty, access to modern sanitation and clean water, enhanced energy security, and reduced air pollution. Cleaner energy technologies can help achieve all of these development objectives.

The United States is cooperating with countries around the world to promote effective climate approaches in the context of broader development strategies. Many developing countries have rapidly advancing industries and considerable technical capabilities. The United States regards these countries as crucial partners in our efforts to address climate change and promote sustainable development.

Technology transfer is a key component of the U.S. development assistance strategy. Elements of this strategy include establishing partnerships with developing and transition countries and creating incentives for investment in environmentally sound technologies. In turn, these climate-related activities complement core U.S. development assistance priorities that include (1) supporting economic growth and social development that protect the resources of the host country, (2) supporting design and implementation of policy and institutional frameworks for sustainable development, and (3) strengthening in-country institutions and capacity that involve and empower the citizens. The intended outcome of such assistance with a technology component is the development of resilient, robust societies, economies, and ecosystems that have the capacity to address the challenges and opportunities of both current and potential climate change conditions.

U.S. federal agencies promote the transfer of climate-friendly technologies through a range of tools and services. These include export credits, project financing, risk guarantees, and insurance to U.S. companies, as well as credit enhancements for host-country financial institutions. U.S. official development assistance and official assistance provide grants for a variety of technology transfer programs. Investments in physical capital, such as plants and equipment, involve U.S. government-supported project financing and credit enhancements, commercial sales, commercial lending, foreign private equity investment, and foreign direct investment. As a major shareholder in international financial institutions, the

United States has supported efforts to promote investments that will lead to cleaner development, especially in the energy area.

U.S. policies also contribute to both the efficient operation of private equity markets and policy and institutional frameworks to support private investments that promote cleaner and more efficient technology deployment and transfer. As highlighted in the 2002 *U.S. Climate Action Report* (CAR), private equity investments in clean energy and other projects relevant to climate change are considerably larger than official development assistance (U.S. DOS 2002). Technology transfer is further strengthened by official activities that support policy and institutional environments in recipient countries and globally.

Since the 2002 CAR, the United States has actively promoted international science and technology partnerships that integrate the efforts of partner governments and private-sector wherewithal to address targeted objectives that can contribute to climate goals. Between 2001 and 2006, U.S. funding for climate change in developing countries totaled approximately $1.4 billion, including $209 million to the Global Environment Facility (GEF) in support of climate change projects (out of a total GEF contribution of approximately $680 million) (Tables 7-1 and 7-2).

The United States has also played a leadership role in establishing a number of international partnerships focused on the development and commercialization of climate-friendly technologies and practices, and new mechanisms to transfer funding to and assist development in developing and transition countries. The Millennium Challenge Corporation[1] and the U.S. Agency for International Development's (USAID's) Global Development Alliance are changing how the United States promotes technology transfer and provides development assistance.

This chapter highlights U.S. international efforts. It outlines U.S. initiatives on climate change and clean development, U.S.-sponsored activities addressing vulnerability and adaptation, financial and technical assistance by U.S. agencies, trade and development financing, and private-sector involvement. It also explains how the United States is helping to meet the challenge of expected future growth in global energy demand while addressing climate change, by promoting approaches that effectively integrate both the near- and long-term environmental and economic goals. Table 7-3 presents more information on several of these efforts.

MAJOR U.S. INITIATIVES: TECHNOLOGY TRANSFER AND FINANCIAL ASSISTANCE

USAID Climate Change Program

Since 1991, USAID has included global climate change in its development funding, spending approximately $2.6 billion on climate-related development projects and programs. Though the approach has gone through several iterations, its main thrust has been to incorporate climate change considerations into development projects, whether their focus is energy, land management, or vulnerability and adaptation. USAID works in developing and transition countries to implement "win-win" solutions that provide climate-related benefits, while also meeting development objectives in the energy and water sectors, urban areas, forest conservation, agriculture, and disaster assistance. These solutions include activities that (1) promote the transfer of clean energy technologies, (2) measure reductions in greenhouse gas (GHG) emissions, (3) promote carbon management through improved land use, (4) support countries to participate more effectively in the United Nations Framework Convention on Climate Change (UNFCCC), and (5) assess vulnerability to the impacts of climate change and increase adaptive capacity.[2]

Group on Earth Observations

Earth observations provide critical input for understanding the Earth system—its weather, climate, oceans, land, geology, natural resources, ecosystems, and natural and human-induced hazards. This input is crucial to achieving sustainable development. The United States hosted the first Earth Observation Summit in Washington, D.C., on July 31, 2003, attended by 33 nations and the European Commission. The intergovernmental *ad hoc* Group on Earth Observations (GEO) formed at that meeting committed to developing a 10-year plan for implementing an integrated Earth Observation System. At the second Earth Observation Summit in Tokyo in April 2004, the GEO, representing 43 nations, adopted a framework for the system of systems, focusing on nine societal benefit areas. In February 2005, at the third Earth Observation Summit in Brussels, the nearly 60 nations of the GEO brought the first phase of the process to a close by adopting *The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan* (GEO 2005), and establishing the new GEO.

The U.S. Group on Earth Observations (U.S. GEO) recently released a strategic plan for implementing the U.S. components of a comprehensive, coordinated, and sustained Earth Observation System (IWGEO and NSTC/CENR 2005). The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). GEOSS and IEOS will facilitate the sharing and applied use of global, regional, and local data from satellites, ocean buoys, weather stations, and other surface and airborne Earth-observing instruments. The end result will be access to an unprecedented amount of environmental information, integrated into new data products and services benefiting societies and economies worldwide. Application of these data through decision-support tools, outreach, and capacity building will both help efforts to mitigate and increase resilience to climate change.[3]

[1] See <http://www.mca.gov/>.
[2] See <http://www.usaid.gov/our_work/environment/climate/index.html>.
[3] See <http://iwgeo.ssc.nasa.gov/>.

TABLE 7-1 U.S. Financial Contributions to the Global Environment Facility: 2001–2006 (Millions of U.S. Dollars)

From 2001 through 2006, the United States contributed $679.44 million to the Global Environment Facility, which has a number of focal areas, including climate change.

Institution	2001	2002	2003	2004	2005	2006	Total
Global Environment Facility	107.80	100.50	146.90	138.40	106.64	79.20	679.44

Source: U.S. Department of the Treasury.

TABLE 7-2 Annual U.S. Financial Contributions to Multilateral Institutions (Millions of U.S. Dollars)

The U.S. government provides direct funding to multilateral institutions and programs in support of sustainable economic development and poverty alleviation. In many cases, a portion of this funding supports climate change activities.

	2001	2002	2003	2004
World Bank Group	**783.273**	**797.400**	**846.095**	**908.929**
International Bank for Reconstruction and Development	0.000	0.000	0.000	0.000
International Development Association	773.295	792.400	844.475	907.812
Multilateral Investment Guarantee Agency	9.978	5.000	1.620	1.117
International Finance Corporation	0.000	0.000	0.000	0.000
Other Multilateral Institutions, Funds, and Programs				
Inter-American Investment Corporation	24.945	18.000	18.232	0.000
Inter-American Development Bank - Multilateral Investment Fund	9.978	0.000	24.431	24.853
Asian Development Bank	0.000	0.000	0.000	0.000
Asian Development Fund	71.842	98.017	97.250	143.569
African Development Bank	6.087	5.100	5.071	5.075
African Development Fund	99.780	100.000	107.371	112.060
European Bank for Reconstruction and Development	35.700	35.779	35.572	35.222
International Fund for Agricultural Development	4.989	20.000	14.906	14.916
NADBank	0.000	0.000	0.000	0.000
United Nations Development Programme	87.091	97.100	100.000	101.398
United Nations Environment Programme	10.000	10.750	10.500	10.935
UNFCCC Supplementary Fund	0.000	0.000	0.000	0.000
Multilateral Scientific, Technological, and Training Programs				
1. OAS Development Assistance Programs	5.500	5.500	5.500	5.468
2. World Food Program	5.000	6.000	0.000	0.000
3. U.N. Development Fund for Women	1.000	1.000	1.000	0.994
4. World Trade Organization	1.000	1.000	2.000	0.994
5. International Civil Aviation Organization	0.300	0.300	0.300	0.994
6. Montreal Protocol Multilateral Fund	26.000	25.000	23.000	20.876
7. International Conservation Programs	5.450	7.700	6.225	6.362
8. Intergovernmental Panel on Climate Change/UNFCCC	6.500	7.400	6.000	5.567
9. International Contributions for Scientific, Educational, and Cultural Activities	1.750	1.750	1.750	1.889
10. World Meteorological Organization	2.000	2.000	2.000	1.988
11. Center for Human Settlements	0.000	0.000	0.250	0.746

Sources: Congressional Budget Justification, World Bank, International Finance Corporation, and Asian Development Bank annual reports.

TABLE 7-3 **Sample U.S. Government Efforts Promoting the Transfer of Climate-Friendly Technologies and Practices**

Since 2001, the United States has established several partnerships with developing and transition countries, with the primary goal of promoting the development and deployment of climate-friendly technologies and practices. Some examples of those partnerships are presented in this table.

Purpose	Description	Recipient Countries or Partners	Sector	Funding	Years in Operation	Factors Enabling Project's Success	Technologies Transferred	Impact on GHG Emissions/Sinks
U.S./China Energy and Environmental Technology Center (EETC)								
Promote the efficient, responsible production and utilization of clean fossil energy; encourage environmental performance, while improving China's quality of life.	Focused on emission-reducing and clean coal technologies, EETC is working with Chinese organizations to create U.S. business opportunities in China's energy sector.	Implemented jointly by the U.S. and Chinese governments, and Tulane and Tsinghua universities.	Energy	$1,000,000 in fiscal years 2004 and 2005; $994,000 in fiscal year 2004.	Created in 1997.	U.S. clean energy and environmental technologies and expertise.		
Famine Early Warning System Network (FEWS NET)								
Establish more effective, sustainable, host country-led networks that reduce vulnerability to food insecurity.	FEWS NET assesses short- to long-term vulnerability to food insecurity with environmental information from satellites and agricultural and socioeconomic information from field representatives; conducts vulnerability assessments, contingency and response planning, aimed at strengthening host country food security networks.	Afghanistan, Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Guatemala, Haiti, Honduras, Kenya, Malawi, Mali, Mauritania, Nicaragua, Niger, Mozambique, Rwanda, Somalia, Sudan, Uganda, Zambia, Zimbabwe	Adaptation	$13 million per year.	FEWS: 1985-2000; FEWS NET: 2000-current.	The combined U.S. environmental monitoring expertise of NASA, NOAA, and USGS; implementation by host country field staff.	Information networks: remote-sensing data acquisition, processing, and analysis; geographic information system (GIS) analytical skills. Equipment to facilitate adaptation: GIS hardware and software.	Not applicable.

TABLE 7-3 (Continued) **Sample U.S. Government Efforts Promoting the Transfer of Climate-Friendly Technologies and Practices**

Purpose	Description	Recipient Countries or Partners	Sector	Funding	Years in Operation	Factors Enabling Project's Success	Technologies Transferred	Impact on GHG Emissions/Sinks
International Nuclear Energy Research Initiative								
Leverage research, development, and demonstration funds through joint work with members of the Generation IV International Forum.	The Brazil project includes studies on instrumentation and controls and human interface technologies for the International Reactor Innovative and Secure (IRIS) design. The Republic of Korea project includes studies on innovative safety technologies for advanced light-water reactors and gas-cooled fast reactors; provides simulation testing, computational data, and analyses relating to reactor physics and materials; and researches sensors and computational technologies.	Brazil and Republic of Korea	Electricity	Brazil: $3 million over 5 years. Republic of Korea: $25 million over 5 years.	60 years, when built.	Results of RD&D will lead to design improvements, making future reactor facilities safer and more efficient.	Safety, reactor physics, and materials technologies.	Reactors operated over 60 years in Brazil and Republic of Korea have the respective potential to displace over 2 and 4 MMT of CO_2 emissions per year, for respective totals in excess of 125 and 250 MMT over their lifetime.
Methane to Markets Partnerships								
Reduce global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce greenhouse gases.	Focuses on cost-effective, near-term methane recovery and use as a clean energy source; creates the framework for encouraging investment in methane capture and use projects.	Argentina, Australia, Brazil, Canada, China, Colombia, Ecuador, Germany, India, Italy, Japan, Mexico, Nigeria, Poland, Republic of Korea, Russia, Ukraine, United Kingdom, United States	Electricity	$53 million over 5 years.	Launched in November 2004.	Encouraging implementation of proven methane capture and use technologies will result in substantial near-term global methane reductions.		By 2015, this effort could lead to annual reductions of methane emissions of up to 50 MMTCE or recovery of 500 billion cubic feet of natural gas. If achieved, these results could lead to stabilized or even declining levels of global atmospheric methane concentrations.

TABLE 7-3 (Continued) **Sample U.S. Government Efforts Promoting the Transfer of Climate-Friendly Technologies and Practices**

Purpose	Description	Recipient Countries or Partners	Sector	Funding	Years in Operation	Factors Enabling Project's Success	Technologies Transferred	Impact on GHG Emissions/Sinks
International Partnership for the Hydrogen Economy (IPHE) Hydrogen Energy Technology Roadmap Development Assistance								
Provide technical assistance to key IPHE partners to accelerate the development of hydrogen and fuel cell technologies and improve their energy, environmental, and economic security.	Both Brazil and China have completed their hydrogen energy technology roadmaps.	China, India, and Brazil	Alternative Energy Technology	$250,000	Established in 2003.	Compiling roadmap and strategy information from IPHE partners will facilitate effective and efficient collaboration on hydrogen and fuel cell RD&D activities.	Expertise in development of hydrogen energy technology roadmapping.	

Asia-Pacific Partnership on Clean Development and Climate

The Asia-Pacific Partnership on Clean Development and Climate is an innovative effort among Australia, China, India, Japan, the Republic of Korea, and the United States to accelerate the development and commercialization of clean energy technologies and practices. Partner countries work together and with their private sectors to meet energy security, national air pollution reduction, and climate change goals in ways that promote sustainable economic growth and poverty reduction. The partnership's inaugural ministerial meeting took place in January 2006 in Sydney, Australia, and resulted in the issuance of a Charter, Communiqué, and Work Plan that guide the work of the partnership. Subsequently, the partnership established eight public/private-sector task forces on (1) cleaner fossil energy, (2) renewable energy and distributed generation, (3) power generation and transmission, (4) steel, (5) aluminum, (6) cement, (7) coal mining, and (8) buildings and appliances. These task forces have drafted action plans that underpin the collaborative activities among partner countries in these sectors. The international roll-out of these action plans took place on October 31, 2006, and included the endorsement of 96 projects.[4] The Asia-Pacific Partnership is a key means of implementing Title XVI of the Energy Policy Act of 2005, which provides for U.S. agencies to undertake a range of activities designed to improve the greenhouse gas intensity levels of large developing countries.

Methane to Markets Partnership

The goal of this action-oriented international initiative is to reduce global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce greenhouse gases. The partnership initially targets four major methane sources: landfills, underground coal mines, natural gas and oil systems, and livestock waste management. It focuses on the development of strategies and markets for the recovery and use of methane through technology development, demonstration, deployment, and diffusion; implementation of effective policy frameworks; identification of ways and means to support investment; and removal of barriers to collaborative project development and implementation. Member countries work in collaboration with the private sector, multilateral development banks, and other governmental and nongovernmental organizations (NGOs) to achieve these objectives. The partnership has the potential to deliver by 2015 annual reductions in methane emissions of up to 50 million metric tons of carbon equivalent (MMTCE) or recovery of 500 billion cubic feet of natural gas.[5]

International Partnership for the Hydrogen Economy

The International Partnership for the Hydrogen Economy (IPHE) is committed to accelerating the development of hydrogen and fuel cell technologies to improve their energy, environmental, and economic security. IPHE was established in 2003 as an international institution to accelerate the transition to a hydrogen

[4] See <http://www.asiapacificpartnership.org/>.
[5] See <www.methanetomarkets.org> and <www.epa.gov/methanetomarkets>.
[6] See <www.iphe.net>.

economy. Developing and emerging economy country partners include India, the Republic of Korea, Brazil, and China. Hydrogen technology roadmaps have been developed in India and Brazil.[6]

Carbon Sequestration Leadership Forum

An international climate change initiative that includes both developed and developing countries, the Carbon Sequestration Leadership Forum (CSLF) is focused on developing improved and cost-effective technologies for the separation and capture of carbon dioxide and its transport and long-term safe storage. CSLF works to make these technologies broadly available internationally and to identify and address more comprehensive issues, such as regulation, relating to carbon capture and storage. Currently 17 CSLF-endorsed projects are underway to evaluate and demonstrate carbon sequestration technologies.[7]

ITER

ITER is a proposed multilateral collaborative project among the United States, China, the European Union, Japan, Russia, India, and the Republic of Korea to design and demonstrate a fusion energy production system with a goal of commercialization by 2050. The United States is participating in negotiations on the siting, construction, operation, deactivation, and decommissioning of ITER.[8]

Generation IV International Forum

The Generation IV International Forum (GIF) is a multilateral partnership of 10 countries and the European Commission that is fostering international cooperation in research and development (R&D) for the next generation of safer, more affordable, and more proliferation-resistant nuclear energy systems. This new generation of nuclear power plants could produce electricity and hydrogen with substantially less waste and without emitting any air pollutants or GHG emissions. Since GIF's formal establishment in July 2001, the United States has led the development of a technology roadmap and has increased support for R&D projects carried out in support of GIF's goals.[9]

Global Nuclear Energy Partnership

The Global Nuclear Energy Partnership (GNEP), led in the United States by the U.S. Department of Energy (DOE), is one component of the Advanced Energy Initiative, announced by President Bush in his 2006 State of the Union Address. GNEP has two major goals: (1) expand carbon-free nuclear energy to meet growing electricity demand worldwide, and (2) promote nonproliferation objectives through the leasing of nuclear fuel to countries that agree to forgo enrichment and reprocessing. GNEP partner countries would consist of both fuel supplier nations and reactor nations. Fuel supplier nations would provide reliable nuclear fuel services to reactor nations through an independent nuclear fuel broker, such as the International Atomic Energy Agency.[10]

U.S./China Energy and Environmental Technology Center

Located at Beijing's Tsinghua University, the U.S./China Energy and Environmental Technology Center (EETC) was established in 1997 by DOE, the U.S. Environmental Protection Agency (EPA), and China's Ministry of Science and Technology. Jointly operated by Tsinghua University and Tulane University, EETC will assist China with environmental and energy policy development and provide information on technologies and expertise from American industry. EETC projects are meant to be broadly applicable to China's power production infrastructure, focused primarily on clean-coal technologies and technologies for emission reduction, while improving the quality of life in China.[11]

Clean Energy Technology Export Initiative

Led by DOE, the Clean Energy Technology Export Initiative seeks to increase market access for U.S. exports of cleaner energy technologies, and to improve interagency collaboration and build partnerships with the private sector. The program builds on and moves beyond prior R&D and capacity-building efforts to address the market needs of a wide spectrum of U.S. private-sector stakeholders, including relatively sophisticated market participants and new market entrants. The program is focused on activities expected to yield results in the near to mid-term (6 months to 4 years).

U.S. Climate Technology Cooperation Gateway

The U.S. Climate Technology Cooperation (US-CTC) Gateway provides the framework for a range of programs, projects, resources, and actions supported by the U.S. government to promote international technology cooperation to address global climate change. The US-CTC Gateway enables climate technology cooperation stakeholders to work together and highlights U.S.-sponsored activities that have resulted in clear, measurable benefits. The US-CTC Gateway is designed to serve as an on-line resource on specific activities and to provide useful information and resources that can allow users to implement climate-friendly technologies and practices throughout the world.[12]

U.S. Clean Energy Initiative

At the August 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, the United States launched a Clean Energy Initiative consisting of three market-oriented, performance-based partnerships: Efficient Energy for Sustainable Development, led by DOE; the Global Village Energy Partnership, led by USAID; and Partnership for Clean Indoor Air, led by EPA. The Clean Energy Initiative's mission is to bring together governments, international organizations, industry, and civil society in partnerships

[7] See <www.cslforum.org>.
[8] See <www.iter.org>.
[9] See <http://gen-iv.ne.doe.gov/GENIVintl-gif.asp>.
[10] See <http://www.gnep.energy.gov/default.html/>.
[11] See <http://www.tulane.edu/~uschina/intro.html>.
[12] See <http://www.usaid.gov/our_work/environment/climate/policies_prog/ghg.html>.

to alleviate poverty and spur economic growth in the developing world by modernizing energy services.[13]

Efficient Energy for Sustainable Development

Efficient Energy for Sustainable Development (EESD) aims to improve the productivity and efficiency of energy systems, while reducing pollution and waste, saving money, and improving reliability through less energy-intensive products, more energy-efficient processes, and production modernization. EESD is helping developing economies get ahead of their development curves by focusing on promoting public leadership in the efficient use of clean energy technologies in public facilities, facilitating locally managed financial programs to attract long-term financing for energy efficiency and renewable energy projects, and building capacity in the local private sector to adopt cleaner and more efficient technologies.[14]

Global Village Energy Partnership

The Global Village Energy Partnership brings together developing and industrialized country governments, public and private organizations, multilateral institutions, consumers, and others in an effort to ensure low-income families have access to modern energy services. The partnership aims to reduce poverty and enhance economic and social development for millions around the world. Its work will be carried out under a 10-year implementation-based program. The partnership's objectives are to catalyze country commitments to village energy programs; bridge the gap among investors, entrepreneurs, and energy users; facilitate policy and market regulatory frameworks; serve as a marketplace for information and best practices; and create and maintain an effective coordination mechanism.[15]

Partnership for Clean Indoor Air

Some three billion people worldwide burn traditional biomass and coal indoors for home cooking and heating. Indoor air pollution from household energy ranks as the fourth leading health risk in developing countries, with women and children being most significantly affected. The Partnership for Clean Indoor Air was created in response to this challenge. Its more than 120 public and private organizations are contributing their resources and expertise to improve health, livelihoods, and quality of life in Asia, Africa, and Latin America by reducing exposure to indoor air pollution from household energy use. The partnership is focusing on four priority areas: meeting social and cultural needs, developing local markets, improving technology design and performance, and monitoring impacts.[16]

EPA Programs for Energy Efficiency

EPA supports several programs that promote energy efficiency in products and buildings.

Energy Efficiency Endorsement Labeling Programs

Drawing on the lessons, experience, information, and tools available from its successful ENERGY STAR program, EPA is working with developing countries (primarily China and India) to enhance their capacity to design and implement their own effective, voluntary energy efficiency endorsement labeling programs. For example, with technical assistance from EPA and other international organizations, the China Standard Certification Center has established a China-specific endorsement label that is now applied to 21 products.[17] It is estimated that by 2014, product labeling will reduce GHG emissions in China by up to 27 MMTCE.

eeBuildings

A second program, eeBuildings, helps building owners, managers, and tenants improve the energy efficiency of their buildings worldwide. eeBuildings forms partnerships with multinational corporations, local businesses and NGOs, government agencies, and other organizations that share eeBuildings' goal of improving energy efficiency to save energy and money. Key elements of eeBuildings are technical resources and training, links to other programs with related goals, and recognition for implementing or promoting energy efficiency in commercial buildings.[18]

Collaborative Labeling and Appliance Standards Program

The Collaborative Labeling and Appliance Standards Program (CLASP) was formed in 1999 as a partnership devoted to promoting best practices in energy efficiency standards and labeling programs in developing and transition countries. CLASP includes the design, implementation, and enforcement of energy efficiency standards and labels for appliances, equipment, and lighting products. Supported by USAID, DOE, and EPA, the partnership includes governments, intergovernmental organizations, industry, NGOs, and technical institutions. CLASP has provided technical support to Argentina, Bahrain, Brazil, Chile, China, Colombia, the Dominican Republic, Ecuador, Egypt, Ghana, India, Mexico, Nepal, Poland, Sri Lanka, Thailand, Tunisia, and Uruguay. It has also supported regional standards and labeling projects in 30 countries. The overall result of energy efficiency standards and labels is to reduce both required investments in power plants and fuel consumption for their operation, with powerful economic gains (e.g., freeing up capital for investments in nonenergy social infrastructure, such as schools, roads, or hospitals) and environmental benefits (e.g., avoiding carbon emissions).[19]

Integrated Environmental Strategies Program

EPA's Integrated Environmental Strategies program engages developing countries to build support for integrated planning to address both local environmental concerns and global GHG emissions. The program promotes the analysis

[13] See <www.sdp.gov>.
[14] See <http://www.sdp.gov/sdp/initiative/c17707.htm>.
[15] See <http://www.gvep.org//>.
[16] See <http://www.epa.gov/iaq/pcia.html and www.PCIAonline.org>.
[17] See <http://www.cecp.org.cn/englishhtml/index.asp>.
[18] See <www.epa.gov/eeBuildings>.
[19] See <http://www.clasponline>.

of and local support for implementation of clean energy technology policies and measures, with multiple public health, economic, and environmental benefits. To date, government agencies, research institutions, businesses, and NGOs in Argentina, Brazil, Chile, China, India, Mexico, the Philippines, and the Republic of Korea have participated in the program.[20]

Central America Greenhouse Gas Inventory Improvement Project

In partnership with the seven nations of Central America, USAID and EPA are carrying out an extensive three-year project to improve the quality and sustainability of national GHG inventories in the region. The project focuses on developing long-term national inventory management systems, improving the methods and data used in the agriculture and the land-use change and forestry sectors, and training regional experts. The project includes experts from the United States, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.[21]

International Renewable Energy Program

The mission of the International Renewable Energy Program (IREP) is to promote international capacity building in support of market-focused transfer of clean energy technology. Application of DOE's world-class technical expertise contributes to U.S. goals for sustainable development and improved trade, security, climate, and environment. IREP activities are focused on capacity building in support of optimal use of energy efficiency and renewable energy technologies, and market and trade development to enhance commercialization of these technologies. To address these needs, IREP provides technical assistance, disseminates information, and conducts trade missions and reverse trade missions.[22]

United States–Asia Environmental Partnership

Since 1992, the United States–Asia Environmental Partnership (US–AEP) has been USAID's primary program in Asia supporting efforts to improve environmental conditions in selected Asian countries. US–AEP has developed valuable partnerships, strengthened the capacities of Asian environmental institutions, addressed the challenges of urbanization and industrialization, and promoted sustainable economic growth to improve the environment and quality of life for the people of Asia. After more than a decade of accomplishments, US–AEP formally concluded on September 30, 2005.

A new USAID regional environmental program was launched in October 2005. This new program continues and extends US–AEP's support of a number of activities promoting regional environmental initiatives, such as the Asian Environmental Compliance and Enforcement Network, ASEAN Sustainable Cities Initiative, and Southeast Asia Water Utilities Network.[23]

Climate Technology Initiative

The Climate Technology Initiative (CTI) is a multilateral cooperative activity that supports implementation of the UNFCCC by fostering international cooperation for accelerated development and diffusion of climate-friendly technologies and practices. CTI was originally established at the first Conference of the Parties to the UNFCCC in 1995. Since July 2003, CTI has been operating under an implementing agreement of the International Energy Agency that includes the United States, Austria, Canada, Denmark, Finland, Germany, Japan, Norway, and the United Kingdom. Through a variety of capacity-building activities, CTI has promoted meaningful technology transfer to and among developing and transition countries. In addition to their current and future environmental benefits, these efforts are promoting near- and long-term global economic and social stability.[24]

Renewable Energy and Energy Efficiency Partnership

Formed at the WSSD in Johannesburg, the United Kingdom-led Renewable Energy and Energy Efficiency Partnership (REEEP) seeks to accelerate and expand the global market for renewable energy and energy efficiency technologies. As the world's largest producer and consumer of renewable energy, and with more renewable energy generation capacity than Germany, Denmark, Sweden, France, Italy, and the United Kingdom combined, the United States is one of 17 partners in REEEP. The United States also actively participated in Germany's Renewables 2004 conference in June 2004, and submitted five action items intended to provide specific technology plans and cost targets for renewable energy technologies using solar, biomass, wind, and geothermal resources.[25]

FOREST CONSERVATION PARTNERSHIPS

Tropical Forest Conservation Act

The Tropical Forest Conservation Act (TFCA) was enacted in 1998 to offer eligible developing countries options to relieve certain official debt owed to the United States, while at the same time to generate funds to support local tropical forest conservation activities. As of June 2006, TFCA programs are being implemented in Bangladesh, Belize, Colombia, El Salvador, Jamaica, Panama (two agreements), Paraguay, Peru, and the Philippines, and agreements for two additional countries are being negotiated. The 12 agreements completed to date will directly generate more than $135 million for tropical forest conservation in these countries over the life of the agreements, and additional resources will be created through returns on investments and matching funds.

[20] See <www.epa.gov/IES>.
[21] See <http://www.usaid.gov/our_work/environment/climate/country_nar/gcap_profile.html>.
[22] See <www.eere.energy.gov/wip/program/international.html>.
[23] See <http://www.usaep.org/transition.html> and <http://www.usaid.gov/locations/asia_near_east/countries/rdma/>.
[24] See <http://www.climatetech.net/>.
[25] See <www.reeep.org>.

A number of other countries have qualified for or expressed interest in the TFCA program, and agreements beyond those mentioned here are anticipated as the program continues to expand. In addition to forest conservation and debt relief, TFCA is intended to strengthen civil society by creating local foundations to support small grants to NGOs and communities. The program also offers a unique opportunity for public–private partnerships. Six of the agreements to date have included more than $7 million in cash raised by U.S.-based NGOs, in addition to the approximately $60 million in appropriated debt-reduction funds contributed by the U.S. government.[26]

President's Initiative Against Illegal Logging

On July 28, 2003, Secretary of State Powell launched the President's Initiative Against Illegal Logging to assist developing countries in combating illegal logging, including the sale and export of illegally harvested timber, and in fighting corruption in the forest sector. The initiative represents the most comprehensive strategy undertaken by any nation to address this critical sustainable development challenge, and reinforces the U.S. leadership role in taking action to counter the problem and preserve forest resources that store carbon. The initiative focuses on three critical regions—the Congo Basin, the Amazon Basin and Central America, and South and Southeast Asia—and four key strategies: good governance, community-based actions, technology transfer, and harnessing market forces.[27]

Congo Basin Forest Partnership

The Congo Basin Forest Partnership (CBFP) studies and implements sustainable natural resource management within the Congo Basin. Announced by Secretary Powell at the WSSD in Johannesburg in 2002, CBFP builds on USAID's Central African Regional Program for the Environment. The U.S. goal in this partnership is to promote economic development, poverty alleviation, improved governance, and natural resource conservation through support for a network of national parks and protected areas, well-managed forestry concessions, and assistance to communities that depend upon the conservation of the outstanding forest and wildlife resources of 11 key landscapes in 6 Central African countries. The climate change impacts of the CBFP include increased carbon sequestration and reduced GHG emissions through preservation of the forest biomass.[28]

Amazon Basin Conservation Initiative

The Amazon Basin Conservation Initiative (ABCI) is a new regional conservation program to support the national governments and civil societies of the Amazon in their efforts to conserve the Amazon Basin's unique and globally important resources. ABCI is the second in a series of initiatives designed to address the shared responsibility of the United States for the stewardship of globally important biodiversity. Over the next five years, USAID plans to make an initial investment of $50 million to support community groups, governments, and public and private organizations in their efforts to conserve the Amazon's globally important biodiversity. This investment will be in addition to the current portfolio of conservation efforts supported by USAID in the region.[29]

U.S.-SPONSORED ACTIVITIES ADDRESSING VULNERABILITY AND ADAPTATION

The United States has undertaken a broad range of activities to assist countries to develop flexible and resilient societies and economies that have the capacity to address both the challenges and the opportunities presented by changing climatic conditions. The United States was one of the first nations to assist developing countries to build core capacity to undertake vulnerability assessments through its Country Studies Program (CSP).[30] Between 1994 and 2001, the CSP helped 56 countries build the human and institutional capacities necessary to assess their vulnerability to climate change. Subsequent activities have built off those efforts, with the goal of furthering knowledge gained through the assessments and mobilizing adaptation actions. This section describes some of the wide-ranging adaptation activities the United States is pursuing.

Building Resilience Through Development Assistance

USAID has broadened its climate change portfolio to include activities aimed at strengthening the capabilities of developing and transition countries to respond to the challenges posed by climate-related impacts and risks. These activities include sustainable forestry and support for agricultural research for stress-resistant crops. USAID seeks to strengthen the capabilities of program managers, host-country institutions, project implementers, and sectoral experts to assess relative vulnerabilities and to evaluate and implement adaptation options for agriculture, water, and coastal zone management projects within USAID's development assistance portfolio. Pilot projects to identify adaptation options are underway in South Africa, Honduras, Mali, and Thailand. Lessons learned from the pilot projects will be incorporated into a guidance manual on adaptation activities for development projects.[31]

Regional Climate Outlook Forums

The National Oceanic and Atmospheric Administration (NOAA) and USAID jointly fund Regional Climate Outlook Forums. These forums have become a principal vehicle for providing advance information about the likely character of seasonal climate in several developing regions. They bring together climate forecasters and forecast users

[26] See <http://www.usaid.gov/our_work/environment/forestry/tfca.html>.
[27] See <http://www.state.gov/r/pa/prs/ps/2003/22843.htm>.
[28] See <http://www.usaid.gov/locations/ sub-saharan_africa/initiatives/cbfp.html>.
[29] See <http://www.usaid.gov/locations/latin_america_caribbean/environment/abci.html>.
[30] See <www.gcrio.org/CSP/webpage.html>.
[31] See <http://www.usaid.gov/our_work/environment/climate/index.html>.

to develop a consensus forecast from multiple predictions and to discuss methods of dissemination and application of information. They provide a unique opportunity for stakeholders to meet, share information and concerns, and forge an informal network to address common problems.

The Hermosillo Project: Vulnerability and Adaptation Support for Mexico

EPA and Mexico's National Institute of Ecology initiated the Hermosillo Project to integrate consideration of climatic risks into the city's policy formation process, with support from USAID. The overarching goals of the project were to identify and evaluate options for adapting to climate stresses on water resources in northern Mexico, work with stakeholders to prioritize these options, and begin a process for evaluating such options for other cities in Mexico and the Americas. Stakeholder involvement in design and implementation, close institutional collaboration at various levels, and coordination of adaptation proposals with local policy priorities were important features of the project.

Famine Early Warning System Network

USAID, the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), the U.S. Department of Agriculture (USDA), and NOAA are collaborating with local, regional, and international partners to provide early-warning and vulnerability information on emerging or evolving food security issues, including information relating to variability and changes in regional climate conditions. A primary goal of the Famine Early Warning System Network (FEWS NET) program is to produce high-quality information for disaster and crisis prediction. FEWS NET provides demand-driven information products that pinpoint and assess emerging or evolving food security problems. Program professionals in the United States and Africa monitor data and information—including remotely sensed as well as ground-based data on meteorological, crop, and rangeland conditions—for early indications of potential threats to food security. The program also works to strengthen African early-warning and response networks by increasing local technical capacity, building and strengthening networks, developing policy-relevant information, and forming consensus about food security problems and solutions.[32]

RANET Program

USAID and NOAA are working with a range of humanitarian and meteorological organizations to provide useful weather and climate information to rural communities. The RANET program (Radio and Internet for the Communication of Hydro-Meteorological and Climate-Related Information for Development) uses reserve capacity on the WorldSpace digital satellite system to transmit forecasts, bulletins, imagery, seasonal assessments, and data to remote areas. The goal of the program is to provide environmental information that assists governments and populations in coping with hydrometeorological hazards and environmental fluctuations. RANET also supports the formation of community groups and associations that are instrumental in disseminating information and extending the network to new communities. The program operates in Africa, South and Southeast Asia, and the Western Pacific.[33]

U.S. FINANCIAL AND TECHNICAL ASSISTANCE

U.S. government agencies provide trade and development financing to developing and transition countries. They facilitate the transfer of climate-friendly technologies by providing official assistance, export credits, project financing, risk guarantees, and insurance to U.S. companies, as well as credit enhancements for host-country financial institutions. Trade and development financing leverages foreign direct investment, foreign private equity investment, and host-country and non-U.S. private capital by decreasing the risk involved in long-term capital-intensive projects and projects in nontraditional sectors.

U.S. Agency for International Development

The Bush Administration's climate change policy states that USAID "serves as a primary vehicle for transferring American energy and sequestration technologies to developing countries to promote sustainable development and minimize their greenhouse gas emissions growth." USAID's foreign assistance and development role is key to the involvement of developing countries in resolving climate change issues, as climate change is a global problem that requires action by all. Meeting the future economic and energy needs of developing countries will require developing and transferring the technologies and expertise necessary to reduce the GHG emissions and natural resource demands of current technologies.[34]

U.S. Environmental Protection Agency

A global leader in methane mitigation and energy efficiency promotion, EPA spearheaded the Methane to Markets Partnership, which focuses on cost-effective, near-term methane recovery and use as a clean energy source. EPA supports the International Collaborative Labeling and Appliance Standards Program, as well as several bilateral programs that encourage energy efficiency. EPA designs and implements innovative programs on a variety of global environmental challenges, including efforts to make transportation cleaner, reduce GHG emissions, and improve local air quality. EPA also works with developing countries on 14 climate change bilaterals.[35]

U.S. Department of Energy

In addition to providing funding support for such interagency activities as the Climate Change Technology Program and

[32] See <www.fews.net>.
[33] See <http://www.ranetproject.net/>.
[34] See <www.usaid.gov>.
[35] See <http://www.epa.gov/>.

the Climate Change Science Program, DOE works directly with foreign governments and institutions to promote dissemination of energy efficiency, renewable energy, and clean energy technologies and practices. Since the 2002 CAR, DOE has launched major international initiatives in key technology areas, including hydrogen, carbon sequestration, and next-generation nuclear power, that involve industrialized, emerging, and developing economies. DOE's International Renewable Energy Program works with foreign governments, industry, and NGOs to help them implement viable activities that address climate change, transportation needs, local air quality, and related health risks. DOE also works with developing countries through 14 climate change bilateral collaborations and participates in market development efforts for clean energy technologies through the Energy Efficiency for Sustainable Development program and the United Kingdom-led Renewable Energy and Energy Efficiency Partnership, both of which are WSSD partnerships.[36]

U.S. Department of State

The U.S. Department of State (DOS) serves as a coordinating agency for transferring technology and providing financial resources to developing countries. DOS has implemented bilateral climate change partnerships with a number of developing countries, which enable DOS to coordinate, monitor, and facilitate both joint projects and assistance to U.S. partners.[37]

U.S. Department of Agriculture

Through its participation in a variety of bilateral agreements, multilateral agreements, and international partnerships, USDA provides technical and financial assistance to help countries carry out a wide set of agriculture- and forest-sector activities that support their efforts to mitigate or adapt to the impacts of climate change. These activities include developing methods and protocols for measuring GHG emissions from agricultural sources, developing methods and protocols to estimate carbon fluxes from forest and agricultural systems, designing and implementing agriculture- and forest-sector components of national GHG inventories, reducing GHG emissions through improved agricultural practices, increasing carbon sequestration through improved forest management (including forest conservation, sustainable forestry, and agroforestry), and encouraging sustainable and renewable bioenergy technology and use.[38]

National Oceanic and Atmospheric Administration

NOAA provides weather, water, and climate services; manages and protects fisheries and sensitive marine ecosystems; conducts atmospheric, climate, and ecosystem research; promotes efficient and environmentally safe commerce and transportation; supports emergency response; and provides vital information in support of homeland security. NOAA's climate mission is to: "Understand and describe climate variability and change to enhance society's ability to plan and respond." NOAA's long-term climate efforts are designed to develop a predictive understanding of variability and change in the global climate system, and to advance the application of this information in climate-sensitive sectors through a suite of process research, observations and modeling, and application and assessment activities.[39]

National Aeronautics and Space Administration

NASA advances scientific knowledge by observing the Earth system from space; assimilating new observations into climate, weather, and other Earth system models; and developing new technologies, systems, and capabilities for its observations, including those with the potential to improve future operational systems managed by NOAA and others. NASA is a major participant in the U.S. Climate Change Science Program and in U.S. activities to support the GEO. NASA's Earth observation data are openly available to all nations, organizations, and individuals, and the Agency has many active partnerships with U.S. and international agencies to facilitate the use of its data in research and operational applications.[40]

U.S. Department of Commerce

The U.S. Department of Commerce recently established an International Clean Energy Initiative that links U.S. companies with foreign markets to facilitate dissemination of clean energy technologies, products, and services. The initiative seeks to realize a vision for enhanced exports of clean energy technology.[41]

TRADE AND DEVELOPMENT FINANCING

U.S. government agencies provide trade and development financing to developing and transition countries. These agencies facilitate the transfer of technologies by providing official assistance, export credits, project financing, risk and loan guarantees, and investment insurance to U.S. companies, as well as credit enhancements for host-country financial institutions. These activities help leverage direct investment by decreasing risks associated with long-term, capital-intensive projects or projects in nontraditional sectors. Several agencies engage in this type of financing, including activities that promote climate change objectives.

Overseas Private Investment Corporation

The Overseas Private Investment Corporation's (OPIC's) core mission is to support economic development by promoting U.S. private investment in developing countries and transition economies. OPIC provides project financing, political risk insurance, and investment guarantees for U.S. company projects covering a range of investments, including many independent power projects in developing countries.

[36] See <www.energy.gov> and <www.iisd.ca/wssd/partnerships.html>.
[37] See <www.state.gov>.
[38] See <www.usda.gov>.
[39] See <www.noaa.gov>.
[40] See <www.nasa.gov>.
[41] See <www.commerce.gov>.

OPIC also supports a variety of funds that make direct equity and equity-related investments in new, expanding, and privatizing companies in emerging market economies. OPIC evaluates all project applications on the basis of their contribution to economic development to ensure the successful implementation of the organization's core developmental mission, and prioritizes the allocation of scarce resources to projects on the basis of their developmental benefits.[42]

Export-Import Bank

The Export-Import Bank (Ex-Im), the export credit agency of the United States, provides financial support to exporters of U.S. equipment and services through its insurance, working capital, and loan guarantee programs. Ex-Im also features an Environmental Exports Program (EEP) that provides enhanced financial support for renewable energy and other environmentally beneficial exports. Under the EEP, Ex-Im provides special support for exports of air, water, and soil pollution cleanup; ecological and forestry management; renewable and alternative energy projects, including photovoltaic, wind, biomass, fuel cells, waste to energy, hydroelectric, clean coal, and geothermal projects; products to measure or monitor air or water quality; equipment to reduce emissions or effluents; environmental impact assessments and ecological studies; environmental training services; and products designed to improve energy efficiency.

Ex-Im also offers foreign buyers extended repayment terms of up to 15 years to cover the purchase of U.S. goods and services for renewable energy projects. This special support is available for exports to wind energy, geothermal energy, tidal, wave power, solar photovoltaic, solar thermal, ocean thermal, sustainable biomass, and certain bioenergy projects. In fiscal year 2006, Ex-Im authorized approximately $9.8 million in loan guarantees, insurance, and working capital guarantees to support U.S. renewable energy exports to various foreign countries.[43]

USAID Development Credit Authority

The Development Credit Authority (DCA) is a broad financing authority that allows USAID to use credit to pursue any of the development purposes specified under the Foreign Assistance Act of 1961, as amended. DCA seeks to provide USAID the flexibility to make more rational choices about appropriate financing tools used in project development, including individual or combined loans, guarantees, and grants. DCA activities are designed and managed by USAID's overseas missions. Credit projects offer several distinct and attractive advantages over other forms of assistance, and leverage and maximize USAID resources by providing access to local private capital, sharing risk to encourage lending, mobilizing local private capital, and enhancing "the demonstration effect."[44] For example, USAID is providing an Indian bank a 10-year, $20 million loan portfolio guarantee to facilitate financing of small-scale renewable energy, energy efficiency, and water conservation projects by small and medium enterprises. This assistance will increase energy access and reduce GHG intensity.

USAID Global Development Alliance

USAID's Global Development Alliance (GDA) business model links U.S. foreign assistance with the resources, expertise, and creativity of governments, business, and civil society. Through public–private partnerships, USAID and its partners combine their assets to address pressing development problems, achieving a solution that would not be possible for any individual partner alone. Through fiscal year 2005, USAID funded 400 alliances, with $1.4 billion of USAID funding leveraging $4.6 billion from partners. To provide an alternative to traditional grants and contracts for nontraditional partners,[45] USAID created a new obligating instrument—the collaborative agreement—that became operational in fiscal year 2005.[46] For example, USAID and General Electric have launched a GDA to pilot commercially viable rural electrification in India using renewable energy systems, thus increasing energy access and economic growth while reducing the growth of GHG emissions.

U.S. Trade and Development Agency

The U.S. Trade and Development Agency (USTDA) is a foreign assistance agency that delivers its program commitments through overseas grants, contracts with U.S. firms, and the use of trust funds at several multilateral development bank groups. The projects supported by USTDA activities represent strong and measurable development priorities in host countries and offer opportunities for commercial participation by U.S. firms. Public- and private-sector project sponsors in developing and middle-income countries request USTDA support to assist them in implementing their development priorities. USTDA's program is designed to help countries establish a favorable trading environment and a modern infrastructure that promotes sustainable economic development. To this end, the agency funds overseas project sponsor access to U.S. private-sector expertise in the areas of (1) trade capacity building and sector development, and (2) project definition and investment analysis. As a priority, USTDA facilitates development in emerging markets by promoting U.S. partnerships in high-priority overseas projects. USTDA has promoted the transfer of climate-friendly technology in the energy, environment, and water resources sectors.[47]

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[42] See <www.opic.gov>.

[43] See <www.exim.gov>.

[44] Demonstration effects are effects on the behavior of individuals caused by observation of the actions of others and their consequences. The term is particularly used in political science and sociology to describe the fact that developments in one place will often act as a catalyst in another place. See <http://www.usaid.gov/our_work/economic_growth_and_trade/development_credit/index.html>.

[45] Nontraditional partners include private industry, local partners, and faith-based organizations that are outside the typical set of contractors and NGOs.

[46] See <http://www.usaid.gov/our_work/global_partnerships/gda/>.

[47] See <http://www.tda.gov/>.

PRIVATE-SECTOR ASSISTANCE

Private-sector participation is critical to the successful transfer of much-needed technical know-how and technologies to most regions of the world. Because the private sector finances, produces, and supplies most climate-friendly technologies, it can provide much of the human and financial capital for effective deployment of these technologies. U.S. government agencies, foundations, NGOs, and businesses each have a different role to play in promoting climate technology transfer to developing and transition countries.

Foreign direct investment (FDI) and commercial lending together represent the primary investment vehicle for long-term, private-sector technology transfer. Along with financial capital, these vehicles also bring other assets vital to production, including technology, knowledge, and skills. It is estimated that U.S. FDI comprises the vast majority of funding going to climate change and related activities in developing and transition countries. However, because most information relating to financing and implementation of private-sector projects is proprietary, very little FDI is reported in Table 7-4.

TABLE 7-4 **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
WORLD	**13,816.37**	**15,878.76**	**38,711.78**	**39,020.63**	**65.73**	**142.78**	**7,439.71**	**8,538.75**	**0.03**	**8,538.75**	**71,752.57**	**72,778.24**	**0.00**	**0.14**	**0.00**	**0.02**	**0.65**	**5.98**	**131,786.85**	**136,365.30**
Africa	**205.40**	**233.16**	**1,931.55**	**1,722.01**	**20.91**	**48.84**	**994.46**	**1,506.44**	**0.00**	**1,506.44**	**891.83**	**1,090.23**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**4,044.15**	**4,601.68**
Africa Regional	0.93	0.13	0.00	0.00	3.95	0.00	21.26	3.57	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.14	3.70
Angola	8.09	7.49	19.62	25.85	0.00	0.00	153.26	352.03	0.00	352.03	21.79	43.40	0.00	0.00	0.00	0.00	0.00	0.00	202.76	428.77
Benin	2.34	0.08	1.47	24.48	0.00	0.00	0.82	2.07	0.00	2.07	6.69	1.73	0.00	0.00	0.00	0.00	0.00	0.00	11.31	28.36
Botswana	0.72	0.62	16.81	5.70	0.00	0.00	0.05	0.01	0.00	0.01	2.65	15.71	0.00	0.00	0.00	0.00	0.00	0.00	20.23	22.04
Burkina Faso	0.32	0.08	0.17	1.66	0.00	0.00	0.16	9.96	0.00	9.96	0.50	1.79	0.00	0.00	0.00	0.00	0.00	0.00	1.14	13.49
Burundi	0.01	0.00	0.91	4.11	0.00	0.00	0.03	1.74	0.00	1.74	0.49	2.62	0.00	0.00	0.00	0.00	0.00	0.00	1.43	8.48
Cameroon	1.66	1.63	111.04	3.90	0.00	0.00	32.27	39.96	0.00	39.96	13.81	7.62	0.00	0.00	0.00	0.00	0.00	0.00	158.78	53.11
Cape Verde	0.18	0.09	5.55	46.50	0.00	0.00	0.00	0.05	0.00	0.05	0.21	0.18	0.00	0.00	0.00	0.00	0.00	0.00	5.94	46.82
Central African Rep.	0.12	0.09	0.28	5.72	0.00	17.03	0.49	8.55	0.00	8.55	1.60	0.80	0.00	0.00	0.00	0.00	0.00	0.00	2.49	32.17
Chad	2.44	0.22	9.87	0.90	0.00	0.00	61.63	30.58	0.00	30.58	16.67	1.85	0.00	0.00	0.00	0.00	0.00	0.00	90.61	33.56
Comoros	0.00	0.00	0.03	0.04	0.00	0.00	0.16	0.53	0.00	0.53	0.95	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.62
Congo (DROC)	0.30	2.56	0.22	1.25	0.00	1.52	3.42	3.20	0.00	3.20	1.99	7.27	0.00	0.00	0.00	0.00	0.00	0.00	5.94	15.80
Congo (ROC)	6.63	1.25	0.88	4.61	0.00	0.00	31.67	28.43	0.00	28.43	8.08	4.27	0.00	0.00	0.00	0.00	0.00	0.00	47.26	38.57
Cote d'Ivoire	3.30	2.18	3.09	9.22	0.00	0.00	18.01	12.42	0.00	12.42	12.69	17.53	0.00	0.00	0.00	0.00	0.00	0.00	37.10	41.35
Djibouti	0.16	0.39	0.30	1.09	0.00	0.00	4.47	5.13	0.00	5.13	0.81	2.15	0.00	0.00	0.00	0.00	0.00	0.00	5.73	8.77
East Africa Regional	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equatorial Guinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eritrea	0.06	0.07	0.81	0.83	0.00	0.00	4.06	0.73	0.00	0.73	1.64	1.45	0.00	0.00	0.00	0.00	0.00	0.00	6.56	3.08
Ethiopia	0.22	0.96	4.36	305.99	0.05	0.00	9.13	23.79	0.00	23.79	3.94	9.56	0.00	0.00	0.00	0.00	0.00	0.00	17.70	340.30
Gabon	0.82	2.15	2.46	2.80	0.00	0.00	44.93	30.78	0.00	30.78	5.89	32.19	0.00	0.00	0.00	0.00	0.00	0.00	54.10	67.92
Gambia	0.08	0.17	0.64	2.24	0.00	0.00	0.01	0.10	0.00	0.10	1.54	1.44	0.00	0.00	0.00	0.00	0.00	0.00	2.26	3.95
Ghana	4.36	8.39	25.19	26.71	0.00	0.90	25.05	60.97	0.00	60.97	22.93	37.49	0.00	0.00	0.00	0.00	0.00	0.00	77.53	134.46
Guinea	0.54	0.68	4.82	5.03	0.00	3.77	13.78	10.84	0.00	10.84	6.48	4.82	0.00	0.00	0.00	0.00	0.00	0.00	25.63	25.14

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Guinea-Bissau	0.00	0.07	0.02	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.88
Kenya	3.44	2.98	441.84	216.51	2.20	2.72	10.65	9.81	0.00	9.81	27.11	31.99	0.00	0.00	0.00	0.00	0.00	0.00	485.23	264.01
Lesotho	0.02	1.25	0.35	0.10	0.00	0.00	0.00	0.03	0.00	0.03	0.35	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.72	1.44
Liberia	0.28	0.58	2.23	8.00	0.00	0.00	4.38	2.22	0.00	2.22	2.16	9.11	0.00	0.00	0.00	0.00	0.00	0.00	9.05	19.91
Madagascar	0.21	0.45	5.20	4.64	8.68	8.23	0.50	3.04	0.00	3.04	4.81	2.60	0.00	0.00	0.00	0.00	0.00	0.00	19.41	18.95
Malawi	2.08	0.20	2.19	0.35	0.00	2.90	4.49	4.38	0.00	4.38	1.16	3.06	0.00	0.00	0.00	0.00	0.00	0.00	9.92	10.89
Mali	1.08	0.50	1.59	4.22	0.00	0.10	8.00	13.49	0.00	13.49	7.27	6.84	0.00	0.00	0.00	0.00	0.00	0.00	17.94	26.15
Mauritania	1.63	1.48	0.23	45.19	0.00	0.00	15.31	15.53	0.00	15.53	3.40	2.95	0.00	0.00	0.00	0.00	0.00	0.00	20.57	65.15
Mauritius	1.01	0.92	7.05	2.81	0.00	0.00	1.33	1.63	0.00	1.63	4.06	5.44	0.00	0.00	0.00	0.00	0.00	0.00	13.45	10.81
Mozambique	0.39	2.07	1.18	3.44	0.00	0.10	12.70	21.01	0.00	21.01	1.60	3.67	0.00	0.00	0.00	0.00	0.00	0.00	15.87	30.28
Namibia	0.97	0.73	175.92	3.84	0.00	1.92	1.63	1.44	0.00	1.44	10.87	3.22	0.00	0.00	0.00	0.00	0.00	0.00	189.39	11.16
Niger	5.81	0.38	5.73	4.22	0.00	0.00	207.92	391.95	0.00	391.95	15.40	7.25	0.00	0.00	0.00	0.00	0.00	0.00	234.86	403.79
Nigeria	59.69	77.65	77.36	140.36	0.00	0.90	7.17	4.07	0.00	4.07	162.34	215.13	0.00	0.00	0.00	0.00	0.00	0.00	306.55	438.11
Rwanda	0.15	0.00	0.46	0.00	0.00	0.00	3.88	2.06	0.00	2.06	6.50	2.13	0.00	0.00	0.00	0.00	0.00	0.00	10.99	4.18
Sahel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	2.49	1.57	6.38	9.45	0.00	1.00	16.10	9.28	0.00	9.28	11.52	10.91	0.00	0.00	0.00	0.00	0.00	0.00	36.50	32.21
Sierra Leone	0.31	0.95	0.64	3.30	0.00	0.00	1.63	1.40	0.00	1.40	3.57	8.24	0.00	0.00	0.00	0.00	0.00	0.00	6.15	13.90
Somalia	0.03	0.02	0.64	0.07	0.00	0.00	0.00	0.62	0.00	0.62	0.66	0.32	0.00	0.00	0.00	0.00	0.00	0.00	1.33	1.03
South Africa	89.45	96.66	976.33	727.72	0.00	0.00	241.83	334.15	0.00	334.15	465.97	558.58	0.00	0.00	0.00	0.00	0.00	0.00	1,773.59	1,717.11
Southern Africa Regional	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sudan	0.00	0.00	0.01	1.58	0.00	0.00	0.00	24.30	0.00	24.30	0.15	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.16	25.96
Swaziland	0.14	0.12	1.02	1.22	0.00	0.00	0.03	0.23	0.00	0.23	2.37	1.55	0.00	0.00	0.00	0.00	0.00	0.00	3.56	3.12
Tanzania	0.57	13.82	4.33	55.13	1.55	2.50	14.67	8.27	0.00	8.27	7.85	10.58	0.00	0.00	0.00	0.00	0.00	0.00	28.97	90.30
Uganda	0.55	0.73	2.32	2.98	4.38	4.40	6.45	14.35	0.00	14.35	9.71	6.59	0.00	0.00	0.00	0.00	0.00	0.00	23.40	29.05
West Africa Regional	0.00	0.00	0.00	0.00	0.00	0.00	2.56	5.85	0.00	5.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.56	5.85
Zambia	1.06	0.18	1.91	1.84	0.10	0.86	6.25	10.06	0.00	10.06	3.92	5.59	0.00	0.00	0.00	0.00	0.00	0.00	13.25	18.54

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Zimbabwe	0.78	0.63	8.10	6.02	0.00	0.00	0.00	1.82	0.00	1.82	7.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.64	8.47
Asia/Near East	**3,285.36**	**4,477.77**	**13,958.94**	**14,680.32**	**6.48**	**26.67**	**2,036.64**	**2,073.39**	**0.01**	**2,073.39**	**35,179.93**	**41,285.41**	**0.00**	**0.13**	**0.00**	**0.00**	**0.20**	**0.13**	**54,467.56**	**62,543.81**
Afghanistan	0.00	80.78	0.00	23.70	0.00	4.00	0.00	50.39	0.00	50.39	0.51	46.16	0.00	0.00	0.00	0.00	0.00	0.00	0.51	205.03
Algeria	25.00	95.58	397.21	168.16	0.00	0.00	115.02	132.61	0.00	132.61	170.34	159.04	0.00	0.00	0.00	0.00	0.00	0.00	707.57	555.39
Asia/Near East Regional	1.30	0.15	0.00	0.05	0.00	2.14	1.70	0.35	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.69
Bahrain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	22.33	43.74	16.01	20.33	0.60	2.50	6.29	11.46	0.00	11.46	43.37	35.28	0.00	0.00	0.00	0.00	0.00	0.00	88.60	113.30
Bhutan	0.12	0.20	0.04	0.10	0.00	0.00	0.01	0.51	0.00	0.51	0.09	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.95
Brunei	13.74	8.77	10.24	14.69	0.00	0.00	4.96	7.30	0.00	7.30	46.28	7.92	0.00	0.00	0.00	0.00	0.00	0.00	75.22	38.69
Burma (Myanmar)	0.39	2.23	0.65	0.72	0.00	0.00	1.71	2.60	0.00	2.60	3.50	0.51	0.00	0.00	0.00	0.00	0.00	0.00	6.25	6.05
Cambodia	26.64	28.49	8.88	29.42	0.00	0.00	0.02	1.36	0.00	1.36	2.93	2.75	0.00	0.00	0.00	0.00	0.00	0.00	38.48	62.02
China	707.62	1,385.08	3,656.58	4,527.54	0.01	0.13	323.87	638.88	0.01	638.88	5,704.12	8,887.15	0.00	0.13	0.00	0.00	0.00	0.03	10,392.20	15,438.94
East Timor	0.00	0.00	0.00	0.00	0.00	0.00	8.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.07	0.00
Egypt	120.57	98.35	1,195.46	626.56	0.00	0.00	200.69	220.39	0.00	220.39	463.89	525.68	0.00	0.00	0.00	0.00	0.00	0.00	1,980.60	1,470.98
Federated States of Micronesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fiji	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
French Polynesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hong Kong	490.18	596.03	988.59	916.89	0.00	0.00	78.52	103.54	0.00	103.54	4,713.60	4,822.01	0.00	0.00	0.00	0.00	0.00	0.00	6,270.90	6,438.46
India	179.40	297.86	706.27	799.33	0.00	0.08	84.77	156.05	0.00	156.05	870.49	1,374.61	0.00	0.00	0.00	0.00	0.20	0.04	1,841.13	2,627.98
Indonesia	59.86	70.80	176.26	170.12	4.00	8.50	190.45	217.43	0.00	217.43	349.91	328.22	0.00	0.00	0.00	0.00	0.00	0.00	780.48	795.08
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.35	0.00	11.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.35
Jordan	0.09	0.00	0.00	0.00	0.00	0.00	14.47	13.23	0.00	13.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.56	13.23
Kiribati	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Korea (ROK)	874.02	1,057.41	4,082.59	3,761.65	0.01	0.00	111.56	193.37	0.01	193.37	9,064.26	10,407.80	0.00	0.00	0.00	0.00	0.00	0.00	14,132.44	15,420.23
Laos	73.25	68.67	0.00	0.67	0.00	0.00	0.30	0.05	0.00	0.05	210.67	309.81	0.00	0.00	0.00	0.00	0.00	0.00	284.22	379.20

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Lebanon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49	0.00	5.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49
Macao	2.30	4.90	7.00	23.20	0.00	0.00	0.08	0.11	0.00	0.11	43.34	35.47	0.00	0.00	0.00	0.00	0.00	0.00	52.72	63.67
Malaysia	195.74	248.96	1,114.42	1,219.12	0.00	0.00	47.54	64.17	0.00	64.17	5,468.94	6,685.00	0.00	0.00	0.00	0.00	0.00	0.00	6,826.63	8,217.24
Maldive Islands	15.93	12.49	3.77	4.28	0.00	0.00	0.12	0.03	0.00	0.03	38.34	46.75	0.00	0.00	0.00	0.00	0.00	0.00	58.16	63.56
Marshall Islands	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	1.28	1.13	0.99	2.25	0.00	0.00	1.04	4.65	0.00	4.65	3.66	5.17	0.00	0.00	0.00	0.00	0.00	0.00	6.37	13.19
Morocco	6.88	0.00	34.36	0.00	0.00	0.00	1.04	0.61	0.00	0.61	38.53	42.56	0.00	0.00	0.00	0.00	0.00	0.00	80.82	43.16
Nauru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.75	3.09	1.78	0.50	1.42	0.58	1.42	0.00	1.42	3.78	11.08	0.00	0.00	0.00	0.00	0.00	0.00	7.94	16.46
New Caledonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Korea	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00
Oman	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	38.07	46.88	64.49	800.48	0.00	0.00	21.26	48.89	0.00	48.89	75.58	193.95	0.00	0.00	0.00	0.00	0.00	0.00	199.40	1,090.20
Palau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	202.71	87.73	373.34	544.71	1.37	7.90	44.97	26.17	0.00	26.17	5,102.03	4,619.47	0.00	0.00	0.00	0.00	0.00	0.06	5,724.42	5,286.04
Qatar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reunion	0.36	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.85	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.85
Samoa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seychelles	0.66	0.00	156.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.71	3.08	0.00	0.00	0.00	0.00	0.00	0.00	172.58	3.08
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	683.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	683.76	0.00
Southeast Asia Regional	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sri Lanka	3.70	30.81	9.29	20.69	0.00	0.00	0.80	2.35	0.00	2.35	37.57	28.71	0.00	0.00	0.00	0.00	0.00	0.00	51.36	82.57
Syria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiwan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Thailand	188.44	177.17	853.95	552.48	0.00	0.00	56.82	96.92	0.00	96.92	2,599.11	2,589.88	0.00	0.00	0.00	0.00	0.00	0.00	3,698.31	3,416.44
Tokelau Islands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tunisia	13.88	0.02	68.04	6.30	0.00	0.00	20.20	18.54	0.00	18.54	30.00	11.48	0.00	0.00	0.00	0.00	0.00	0.00	132.13	36.34
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turks & Caicos Islands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vanuatu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vietnam	20.89	32.78	30.33	445.10	0.00	0.00	16.64	41.59	0.00	41.59	78.80	104.89	0.00	0.00	0.00	0.00	0.00	0.00	146.67	624.36
West Bank/ Gaza	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yemen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.00	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58
Europe/ Eurasia	**219.46**	**259.65**	**652.59**	**1,123.01**	**4.85**	**1.44**	**155.06**	**168.28**	**0.00**	**168.28**	**822.65**	**1,001.21**	**0.00**	**0.02**	**0.00**	**0.02**	**0.00**	**3.79**	**1,854.60**	**2,557.42**
Albania	1.61	1.06	1.33	0.99	0.00	0.00	7.57	2.22	0.00	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.50	4.27
Armenia	5.11	10.05	0.00	0.00	0.00	0.00	9.07	9.74	0.00	9.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.70	14.17	23.49
Azerbaijan	0.00	1.95	0.00	0.00	0.00	0.00	5.23	2.68	0.00	2.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.23	4.62
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bosnia & Herzegovina	3.58	0.77	4.00	4.17	0.00	0.00	0.08	0.33	0.00	0.33	8.11	10.47	0.00	0.00	0.00	0.00	0.00	0.00	15.77	15.74
Bulgaria	2.26	4.09	9.94	18.24	1.25	0.00	4.52	7.25	0.00	7.25	27.72	39.56	0.00	0.00	0.00	0.00	0.00	0.00	45.68	69.14
Central Asia Regional	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.53
Croatia	5.04	8.64	19.55	26.66	0.00	0.00	27.6	86.06	0.00	6.06	25.36	28.53	0.00	0.00	0.00	0.00	0.00	0.00	77.63	69.89
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Rep.	18.17	33.46	214.53	169.21	0.00	0.00	9.01	23.27	0.00	23.27	147.93	255.21	0.00	0.00	0.00	0.00	0.00	0.00	389.64	481.15
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Europe & Eurasia Regional	9.19	3.07	0.00	0.00	1.22	0.39	0.59	0.14	0.00	0.14	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	3.60
Georgia	18.13	9.67	0.00	0.00	1.63	0.00	2.51	6.37	0.00	6.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.28	16.05

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Hungary	43.64	80.18	94.38	552.14	0.00	0.00	25.73	32.72	0.00	32.72	164.51	175.92	0.00	0.00	0.00	0.00	0.00	0.00	328.27	840.97
Kazakhstan	5.28	1.75	0.00	0.00	0.00	0.00	0.84	0.41	0.00	0.41	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.08	6.11	2.26
Kosovo	0.00	0.92	0.00	0.00	0.00	0.00	2.34	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34	2.92
Kyrgyzstan	0.75	0.80	0.00	0.00	0.00	0.00	1.16	0.62	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.91	1.42
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	2.64	0.74	3.62	1.06	0.00	0.00	2.78	0.68	0.00	0.68	11.19	8.10	0.00	0.00	0.00	0.00	0.00	0.00	20.22	10.58
Moldova	4.58	0.00	0.00	0.00	0.00	0.00	1.95	10.53	0.00	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.53	10.53
Montenegro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Poland	22.41	30.91	96.33	150.00	0.00	0.00	26.18	30.00	0.00	30.00	261.76	244.51	0.00	0.00	0.00	0.00	0.00	0.00	406.68	455.41
Romania	12.20	36.20	178.99	67.88	0.00	0.00	8.97	10.60	0.00	10.60	103.79	126.28	0.00	0.00	0.00	0.00	0.00	0.00	303.94	240.96
Russia	1.30	3.00	0.00	0.00	0.75	1.05	0.70	0.40	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	4.45
Serbia	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.30	0.00	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.30
Slovak Rep.	2.91	3.14	6.22	32.33	0.00	0.00	2.91	3.02	0.00	3.02	25.45	44.15	0.00	0.00	0.00	0.00	0.00	0.00	37.49	82.66
Slovenia	9.28	8.17	17.87	39.76	0.00	0.00	2.86	2.26	0.00	2.26	39.52	43.35	0.00	0.00	0.00	0.00	0.00	0.00	69.53	93.53
Tajikistan	0.10	0.50	0.00	0.00	0.00	0.00	0.57	0.38	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.88
Turkmenistan	0.35	0.02	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.12
Ukraine	47.65	16.76	0.00	0.00	0.00	0.00	8.64	8.25	0.00	8.25	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	56.29	25.03
Uzbekistan	0.25	0.00	0.00	0.00	0.00	0.00	0.64	0.93	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.93
Yugoslavia	1.05	2.80	5.84	60.56	0.00	0.00	1.44	4.31	0.00	4.31	7.32	25.12	0.00	0.00	0.00	0.00	0.00	0.00	15.65	92.79
Latin America/ Caribbean	**10,090.11**	**10,905.04**	**22,168.65**	**21,495.12**	**29.47**	**44.28**	**4,242.76**	**4,708.00**	**0.00**	**4,708.00**	**34,858.14**	**29,401.39**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.71**	**71,389.13**	**66,554.53**
Anguilla	0.66	0.56	1.87	1.64	0.00	0.00	0.56	1.55	0.00	1.55	2.73	2.96	0.00	0.00	0.00	0.00	0.00	0.00	5.82	6.70
Antigua & Barbuda	3.28	4.01	14.54	11.73	0.00	0.00	1.05	1.99	0.00	1.99	14.04	12.35	0.00	0.00	0.00	0.00	0.00	0.00	32.91	30.09
Argentina	177.16	144.38	399.72	378.96	0.00	0.00	227.06	249.51	0.00	249.51	1,005.13	547.44	0.00	0.00	0.00	0.00	0.00	0.00	1,809.07	1,320.29
Aruba	9.11	10.42	17.88	15.91	0.00	0.00	2.37	12.81	0.00	12.81	78.63	38.32	0.00	0.00	0.00	0.00	0.00	0.00	107.99	77.46
Bahamas	32.72	40.85	96.15	92.89	0.00	0.00	38.90	19.84	0.00	19.84	96.82	102.20	0.00	0.00	0.00	0.00	0.00	0.00	264.59	255.77
Barbados	12.53	13.44	15.08	20.84	0.00	0.00	5.56	10.02	0.00	10.02	63.09	65.89	0.00	0.00	0.00	0.00	0.00	0.00	96.26	110.20

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Belize	8.13	7.28	20.58	15.50	0.00	0.00	5.31	3.03	0.00	3.03	25.52	20.19	0.00	0.00	0.00	0.00	0.00	0.00	59.55	46.00
Bermuda	13.85	12.10	53.35	110.77	0.00	0.00	2.49	4.84	0.00	4.84	61.96	70.57	0.00	0.00	0.00	0.00	0.00	0.00	131.65	198.28
Bolivia	7.13	12.97	19.16	16.73	4.95	1.80	52.48	38.38	0.00	38.38	65.06	47.15	0.00	0.00	0.00	0.00	0.00	0.00	148.77	117.04
Brazil	1,400.64	406.62	3,431.13	3,099.63	2.50	3.56	719.59	761.14	0.00	761.14	1,797.03	1,220.55	0.00	0.00	0.00	0.00	0.00	0.00	7,350.89	5,491.51
British Virgin Islands	3.27	2.97	62.03	346.24	0.00	0.00	1.67	1.96	0.00	1.96	2,148.70	1,158.58	0.00	0.00	0.00	0.00	0.00	0.00	2,215.66	1,509.74
Caribbean Regional	0.55	0.00	0.00	0.00	0.00	0.98	0.00	1.74	0.00	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	2.72
Cayman Islands	6.76	18.00	24.04	49.39	0.00	0.00	2.44	4.08	0.00	4.08	23.20	53.92	0.00	0.00	0.00	0.00	0.00	0.00	56.43	125.38
Central America Regional	0.00	0.00	0.00	0.00	4.56	5.60	0.00	1.72	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56	7.32
Chile	144.46	183.04	449.39	359.47	0.00	0.00	337.22	443.61	0.00	443.61	780.83	710.18	0.00	0.00	0.00	0.00	0.00	0.00	1,711.89	1,696.29
Colombia	178.47	199.14	276.10	294.06	0.00	0.00	303.55	345.93	0.00	345.93	740.17	791.36	0.00	0.00	0.00	0.00	0.00	0.00	1,498.29	1,630.49
Costa Rica	109.62	110.65	215.90	207.63	0.00	0.00	36.99	35.77	0.00	35.77	596.16	1,063.73	0.00	0.00	0.00	0.00	0.00	0.00	958.67	1,417.78
Dominica Islands	0.59	1.06	1.55	1.60	0.00	0.00	0.67	0.61	0.00	0.61	5.65	6.94	0.00	0.00	0.00	0.00	0.00	0.00	8.45	10.21
Dominican Republic	204.69	341.29	206.85	147.69	0.00	0.19	62.90	28.94	0.00	28.94	750.99	444.34	0.00	0.00	0.00	0.00	0.00	0.00	1,225.44	962.45
Ecuador	71.17	68.09	117.43	92.72	5.30	5.66	177.22	171.16	0.00	171.16	246.86	310.46	0.00	0.00	0.00	0.00	0.00	0.00	617.99	648.09
El Salvador	23.12	24.87	37.27	146.56	0.00	0.00	12.94	17.15	0.00	17.15	177.81	228.62	0.00	0.00	0.00	0.00	0.00	0.00	251.14	417.20
French Guiana	0.71	0.53	7.72	2.60	0.00	0.00	0.81	1.06	0.00	1.06	5.17	3.48	0.00	0.00	0.00	0.00	0.00	0.00	14.42	7.66
Grenada Islands	4.42	5.80	2.81	3.05	0.00	0.00	2.10	0.60	0.00	0.60	115.08	220.63	0.00	0.00	0.00	0.00	0.00	0.00	124.40	230.09
Guadeloupe	2.30	1.36	3.50	3.35	0.00	0.00	1.64	0.58	0.00	0.58	7.99	8.10	0.00	0.00	0.00	0.00	0.00	0.00	15.42	13.40
Guatemala	59.45	51.72	86.76	118.93	0.00	1.88	45.90	61.19	0.00	61.19	115.58	153.48	0.00	0.00	0.00	0.00	0.00	0.00	307.69	387.20
Guyana	12.51	6.47	3.60	6.12	0.00	0.00	10.57	4.35	0.00	4.35	135.44	204.50	0.00	0.00	0.00	0.00	0.00	0.00	162.12	221.45
Haiti	25.66	33.62	23.91	23.73	0.00	0.00	9.23	5.48	0.00	5.48	24.20	28.11	0.00	0.00	0.00	0.00	0.00	0.00	83.00	90.95
Honduras	54.96	68.08	52.25	124.15	2.89	0.75	18.22	24.29	0.00	24.29	131.78	151.14	0.00	0.00	0.00	0.00	0.00	0.00	260.10	368.41

TABLE 7-4 (Continued) **2001 and 2004 U.S. Direct Financial Contributions Related to Implementation of the UNFCCC** (Millions of U.S. Dollars)

RECIPIENT COUNTRY/ REGION	MITIGATION												ADAPTATION						TOTALS	
	Energy		Transport		Forestry		Agriculture		Waste Management		Industry		Capacity Building		Coastal Zone Management		Other Vulnerability Studies			
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Jamaica	45.56	40.06	99.56	73.26	1.94	1.38	28.87	23.59	0.00	23.59	161.51	143.64	0.00	0.00	0.00	0.00	0.00	0.00	337.44	281.93
Latin America Regional	1.70	1.99	0.00	0.00	2.03	10.60	0.60	2.64	0.00	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.33	15.23
Martinique	0.80	0.65	4.77	6.24	0.00	0.00	1.02	0.86	0.00	0.86	112.64	76.49	0.00	0.00	0.00	0.00	0.00	0.00	119.24	84.24
Mexico	6,908.87	8,594.34	15,258.10	14,662.68	3.20	3.81	1,007.86	1,335.41	0.00	1,335.41	18,636.35	15,859.78	0.00	0.00	0.00	0.00	0.00	0.71	41,814.38	40,456.74
Montserrat Islands	0.50	0.12	0.26	0.28	0.00	0.00	0.00	0.48	0.00	0.48	4,779.12	3,664.99	0.00	0.00	0.00	0.00	0.00	0.00	4,779.88	3,665.88
Nicaragua	19.91	25.26	23.84	29.98	0.49	0.50	22.65	22.45	0.00	22.45	25.66	39.51	0.00	0.00	0.00	0.00	0.00	0.00	92.55	117.70
Panama	57.96	43.59	101.58	278.71	0.00	5.12	23.92	30.92	0.00	30.92	165.10	128.32	0.00	0.00	0.00	0.00	0.00	0.00	348.55	486.65
Paraguay	3.47	7.38	6.51	8.66	0.00	0.93	2.27	1.45	0.00	1.45	69.38	88.50	0.00	0.00	0.00	0.00	0.00	0.00	81.63	106.92
Peru	56.08	64.75	83.45	87.09	1.62	1.51	207.69	219.59	0.00	219.59	241.68	264.82	0.00	0.00	0.00	0.00	0.00	0.00	590.52	637.76
Saint Kitts-Nevis	9.39	15.43	6.07	4.05	0.00	0.00	0.65	1.29	0.00	1.29	233.22	365.87	0.00	0.00	0.00	0.00	0.00	0.00	249.33	386.64
Saint Lucia Islands	3.30	2.11	3.50	4.38	0.00	0.00	1.04	1.17	0.00	1.17	173.11	165.90	0.00	0.00	0.00	0.00	0.00	0.00	180.94	173.55
Saint Pierre & Miquelon	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.73	3.71	0.00	0.00	0.00	0.00	0.00	0.00	1.76	3.71
Saint Vincent & Grenadines	1.24	2.27	2.01	3.10	0.00	0.00	1.14	0.45	0.00	0.45	6.70	9.00	0.00	0.00	0.00	0.00	0.00	0.00	11.09	14.82
Suriname	4.68	6.10	9.02	13.02	0.00	0.00	9.91	13.41	0.00	13.41	16.45	22.29	0.00	0.00	0.00	0.00	0.00	0.00	40.05	54.81
Trinidad & Tobago	52.39	64.26	60.01	62.85	0.00	0.00	199.65	169.96	0.00	169.96	194.79	178.40	0.00	0.00	0.00	0.00	0.00	0.00	506.83	475.48
Uruguay	13.24	8.61	21.42	28.79	0.00	0.00	7.54	7.22	0.00	7.22	65.59	44.38	0.00	0.00	0.00	0.00	0.00	0.00	107.79	89.00
Venezuela	343.09	258.77	847.96	540.16	0.00	0.00	648.52	623.76	0.00	623.76	759.52	680.62	0.00	0.00	0.00	0.00	0.00	0.00	2,599.08	2,103.31
Other Global Programs	**16.06**	**3.15**	**0.05**	**0.18**	**4.02**	**21.55**	**10.79**	**82.64**	**0.02**	**82.64**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.45**	**0.35**	**31.41**	**107.86**

8 Research and Systematic Observation

Climate change and climate variability play important roles in shaping the environment, infrastructure, economy, and other aspects of life worldwide. The United States continues to lead the world in research on climate and other global environmental changes, funding a significant portion of the world's climate change research to provide a sound scientific basis for national and international decisions regarding these changes.

With the goal of improving understanding of the science behind climate change, President Bush launched the interagency Climate Change Science Program (CCSP) in February 2002, building on strong U.S. commitment to research on global change. With its $1.5 billion annual investment in monitoring and predicting global change, CCSP is improving understanding of the natural and human-induced changes in the Earth's global environmental system.

The United States also conducts a robust technology research, development, demonstration, and commercialization effort coordinated through the multi-agency Climate Change Technology Program (CCTP). Since 2003, the United States has invested nearly $3 billion annually to facilitate more rapid development and commercialization of advanced and cost-competitive technologies to help meet the Nation's long-term goal of reducing, and eventually reversing, greenhouse gas (GHG) emissions. CCSP and CCTP collaborate to address issues at the intersection of science and technology, such as the evaluation of approaches to sequestration, anthropogenic GHG emissions monitoring, and energy technology development and market penetration scenarios.

Long-term, high-quality observations of the global environmental system are essential for understanding and evaluating Earth system processes. The United States contributes to the development and operation of global observing systems that combine data streams from both research and operational observing platforms to provide a comprehensive measure of climate system variability and climate change. The United States supports multiple oceanic, atmospheric, terrestrial, and space-based systems, working with international partners to enhance observations and improve data quality and availability.

In developing the roadmap for CCSP, the United States recognized the need for enhanced observations and the importance of international cooperation in this area. To address these issues, the United States initiated the first intergovernmental, ministerial-level Earth Observation Summit, which was held in July 2003. At the third Earth Observation Summit, in Brussels in 2005, nearly 60 countries adopted a 10-year plan for implementing a Global Earth Observation System of Systems (GEOSS), that addresses multiple environmental data needs, including climate, weather, biodiversity, natural disasters, and water and energy resource management (GEO 2005). With its focus on climate science, technology, and Earth observations, the United States is at the forefront of finding long-term answers to the complicated issue of global climate change.

THE U.S. CLIMATE CHANGE SCIENCE PROGRAM

CCSP[1] is a collaborative interagency program that integrates the U.S. Global Change Research Program (USGCRP) with the Administration's Climate Change Research Initiative (CCRI). CCSP adds value to the individual Earth and climate science missions of its 13 participating federal agencies and their national and international partners by coordinating research and information to achieve results that no single agency, or small group of agencies, could attain. In addition to integrating research and observational approaches across disciplinary boundaries, CCSP is working to create a more seamless approach among the theory, modeling, observations, and applications that are required to address the multiple scientific challenges posed by climate change and variability.

Development of the CCSP Strategic Plan

In July 2002, CCSP began a process to create a 10-year strategic plan, soliciting and comprehensively examining the research and observation needs of national and international climate change scientists and stakeholders. In November 2002, the Bush Administration released a "discussion" draft of the CCSP strategic plan for public review (CCSP 2002). Guided by the priority information needs identified by scientists and stakeholders, the discussion draft outlined a comprehensive, collaborative approach for developing a more accurate understanding of climate change and its potential impacts.

External comments, obtained through well-attended workshops, public review periods, and multiple reviews by the National Academies' National Research Council (NRC), played an important role in revising the draft plan. After consideration of all of the external input and extensive comments from the internal U.S. government review process, the Bush Administration released the final *Strategic Plan for the U.S. Climate Change Science Program* in July 2003 (CCSP and SGCR 2003a), along with its shorter companion document, *The U.S. Climate Change Science Program—Vision for the Program and Highlights of the Scientific Strategic Plan* (CCSP and SGCR 2003b). The *Strategic Plan* is the first comprehensive update of a U.S. national plan for climate and global change research since the original USGCRP strategy was issued at the program's inception in 1990.

In February 2004, the NRC review committee issued its second public report on the plan, *Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan* (NRC 2004). This report expressed the committee's conclusions on the content, objectivity, quality, and comprehensiveness of the final *Strategic Plan*, on the process used to produce it, and on the proposed process for developing subsequent findings to be reported by CCSP. The NRC review made a number of recommendations on implementing the plan, concluding:

The Strategic Plan for the U.S. Climate Change Science Program articulates a guiding vision, is appropriately ambitious, and is broad in scope. It encompasses activities related to areas of long-standing importance, together with new or enhanced cross-disciplinary efforts. It appropriately plans for close integration with the complementary Climate Change Technology Program. The CCSP has responded constructively to the National Academies review and other community input in revising the strategic plan. In fact, the approaches taken by the CCSP to receive and respond to comments from a large and broad group of scientists and stakeholders, including a two-stage independent review of the plan, set a high standard for government research programs. As a result, the revised strategic plan is much improved over its November 2002 draft, and now includes the elements of a strategic management framework that could permit it to effectively guide research on climate and associated global changes over the next decades. Advancing science on all fronts identified by the program will be of vital importance to the nation.

CCSP Vision

Over the past 15 years, the United States has invested heavily in scientific research, monitoring, data management, and assessment for climate change analyses to build a foundation of knowledge for decision making. The seriousness of the issues and the unique role that science can play in helping to inform society's course give rise to CCSP's guiding vision: *A nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.*

CCSP Mission

The core precept that motivates CCSP is that the best possible scientific knowledge should be the foundation for the information required to manage climate variability and change, and related aspects of global change. Thus, CCSP's mission is to: *Facilitate the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication.*

CCSP Core Approaches

CCSP employs the following core approaches in working toward its goals:[2]

Scientific Research: Plan, Sponsor, and Conduct Research on Changes in Climate and Related Systems—The greatest percentage of the CCSP budget is devoted to continuing the essential ongoing investment in scientific knowledge, facilitating the discovery of the unexpected, and advancing the frontiers of science. CCSP agencies coordinate their work through seven interdisciplinary research elements and four cross-cutting elements, which together support scientific research across a wide range of interconnected issues of climate and global change. The CCSP research elements are: (1) Atmospheric Composition, (2) Climate Variability and Change (including Climate Modeling), (3) Global Water Cycle, (4) Land-Use/Land-Cover Change, (5) Global Carbon Cycle, (6) Ecosystems, and (7) Human Contributions and Responses/Decision Support. The four cross-cutting elements are: (1) Observations, (2) Modeling, (3) Communications, and (4) International Research

[1] See <http://www.climatescience.gov>.

[2] For greater detail, see <http://www.climatescience.gov/Library/stratplan2003/final/default.htm>.

and Cooperation. CCSP encourages evolution of the research elements over the coming decade in response to new knowledge and societal needs.

Observations: Enhance Observations and Data Management Systems to Generate a Comprehensive Set of Variables Needed for Climate-Related Research—Prior and current investments in new Earth observations will significantly enhance knowledge of environmental variables in the coming years. But enhanced global and regional integration of observation and data management systems, especially to help generate new and improved decision-support products, will also be needed. CCSP is working to increase the capacity to prioritize, ensure the quality of, archive, and disseminate (in useful format) the large quantity of available observations.

The intergovernmental Group on Earth Observations (GEO) is committed to continuing progress toward the development of a comprehensive, coordinated, and sustained GEOSS. In February 2005, the GEO released a 10-year implementation plan summarizing the essential steps to be taken by a global community of nations and intergovernmental, international, and regional organizations (GEO 2005). The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). In March 2005, the National Science and Technology Council's Committee on Environment and Natural Resources (CENR) released the *Strategic Plan for the U.S. Integrated Earth Observation System* (IWGEO and NSTC/CENR 2005). The plan addresses the policy, technical, fiscal, and societal benefit components of this integrated system, and created the U.S. Group on Earth Observations (USGEO) as a standing subcommittee of CENR. CCSP is coordinating its observation priorities with USGEO as IEOS is developed.

Decision Support: Develop Improved Science-Based Resources to Aid Decision Making—CCSP is encouraging improved interactions with stakeholders and is developing resources to support public discussion and planning, adaptive management, and policymaking. The program is also encouraging development of new methods, models, and other resources that facilitate economic analysis, decision making under conditions of uncertainty, and integration and interpretation of information from the natural and social sciences in particular decision contexts.

Communications: Communicate Results to Domestic and International Scientific and User Communities, Stressing Openness and Transparency—CCSP has a responsibility to communicate with interested partners in the United States and throughout the world, and to learn from these partners on a continuing basis. CCSP aims to improve dialogue with public- and private-sector constituencies and to provide users of climate change information with adequate opportunities to help frame important scientific research activities. This dialogue is an essential component of the development of decision-support tools.

CCSP Scientific Goals

In its *Strategic Plan*, CCSP adopted five overarching scientific goals (CCSP and SGCR 2003a). By developing information responsive to these goals, the program ensures that it addresses the most important climate-related issues. The following five goals frame what might be termed an "end-to-end" approach to climate and global change research, including observations, understanding processes, projections of future change, understanding potential consequences of change, and applications of knowledge to management decisions.

- *Goal 1*—Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.
- *Goal 2*—Improve quantification of the forces bringing about changes in the Earth's climate and related systems.
- *Goal 3*—Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.
- *Goal 4*—Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.
- *Goal 5*—Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

Synthesis and Assessment Products

CCSP is producing synthesis and assessment products to support informed discussion and decision making on climate variability and change by policymakers, resource managers, stakeholders, the media, and the general public. These products provide current evaluations of the identified science foundation that can be used for informing public debate, policy development, and adaptive management decisions, and for defining and setting the program's future direction and priorities.

U.S. government and nongovernmental researchers are producing 21 synthesis and assessment (S&A) products. Each product will undergo a rigorous peer review by scientists, stakeholders, and the general public, as well as final approval by the U.S. government. These products constitute an important new form of topic-driven integration of U.S. global change assessment efforts and will be disseminated by the U.S. government at various dates between 2006 and 2008. Box 8-1 presents the list of products associated with the five CCSP goals.

The first of these products, S&A Product 1.1—*Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*—was released on May 9, 2006 (CCSP and SGCR 2006b). S&A Product 1.1 addresses some of the long-standing difficulties that have impeded understanding changes in atmospheric temperatures and the basic causes of these changes. It is an important contribution toward improving understanding of climate change and human influences on temperature trends. S&A Product 1.1 and other S&A products to follow will

BOX 8-1 Summary of the 21 Climate Change Science Program Synthesis and Assessment Products

Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.

1.1 Temperature trends in the lower atmosphere: Steps for understanding and reconciling differences. (Released on May 9, 2006).
1.2 Past climate variability and change in the Arctic and at high latitudes.
1.3 Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.

Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.

2.1 (A) Scenarios of greenhouse gas emissions and atmospheric concentrations, and (B) global change scenarios: their development and use.
2.2 North American carbon budget and implications for the global carbon cycle.
2.3 Aerosol properties and their impacts on climate.
2.4 Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet exposure and climate change.

Goal 3: Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.

3.1 Climate models: an assessment of strengths and limitations for user applications.
3.2 Climate projections based on emission scenarios for long-lived radiatively active trace gases and future climate impacts of short-lived radiatively active gases and aerosols.
3.3 Weather and climate extremes in a changing climate.
3.4 Abrupt climate change.

Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.

4.1 Coastal elevations and sensitivity to sea level rise.
4.2 State-of-knowledge of thresholds of change that could lead to discontinuities in some ecosystems and climate-sensitive resources.
4.3 The effects of climate change on agriculture, land resources, water resources, and biodiversity.
4.4 Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources.
4.5 Effects of climate change on energy production and use in the United States.
4.6 Analyses of the effects of global change on human health and welfare and human systems.
4.7 Impacts of climate variability and change on transportation systems and infrastructure: Gulf Coast study.

Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

5.1 Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.
5.2 Best-practice approaches for characterizing, communicating, and incorporating scientific uncertainty in climate decision making.
5.3 Decision-support experiments and evaluations using seasonal-to-interannual forecasts and observational data.

constitute a valuable source of information for policymakers, researchers, and other interested parties.

International Research and Cooperation

International coordination and cooperation are essential to improve understanding of climate variability and change. As described in the CCSP *Strategic Plan*, an international approach to research is required because of the global scope of the climate system, as well as limitations to the scientific capacity and financial resources of any one nation (CCSP and SGCR 2003a).

The goals of the U.S. efforts to promote international cooperation in support of CCSP are:

- Actively promote and encourage cooperation between U.S. scientists and scientific institutions and agencies and their counterparts around the globe.
- Expand observing systems to provide global observational coverage of variability and change in the atmosphere and oceans and on land.
- Ensure that the data collected are of the highest quality possible, suitable for both research and forecasting, and that these data are exchanged and archived on a timely and effective basis among all interested scientists and end users.
- Support development of scientific capabilities and the application of results in developing countries to promote the fullest possible participation by scientists and scientific institutions in these countries.

On behalf of the U.S. government and the scientific community, CCSP participates in and provides input to, major international scientific and related organizations. In addition, CCSP provides support to maintain the central coordinating

infrastructure of major international research programs and activities that complement CCSP and U.S. government goals and objectives for climate science.

The U.S. government also supports the environmental programs of other countries that have reduced GHG emissions, while promoting energy efficiency, forest protection, biodiversity conservation, and other development goals. This "multiple benefits" approach to climate change helps developing and transition countries expand economically without sacrificing environmental protection.

CCSP has provided scientific resources and/or direct funding support for international projects and programs, including the Arctic Climate Impact Assessment, the International Geosphere-Biosphere Programme, Diversitas, the International Human Dimensions Programme, the World Climate Research Programme, SysTem for Analysis Research and Training, the Intergovernmental Panel on Climate Change, and the Northern Eurasia Earth Science Partnership Initiative. The United States has also established bilateral (climate-related) partnerships with Australia, Brazil, Canada, China, Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), the European Union, Germany, India, Italy, Japan, Mexico, New Zealand, the Republic of Korea, the Russian Federation, and South Africa.

CCSP Workshop: Climate Science in Support of Decision Making

CCSP has committed to support public discussion and planning, adaptive management, and policymaking. In November 2005, the program reported on its progress and future plans regarding these three decision-support goals at a CCSP-sponsored public workshop, *Climate Science in Support of Decision Making* (CCSP 2005). The more than 700 participants included an international audience of climate scientists, decision makers, and users of information on climate variability and change, and more than 260 abstracts were submitted. A variety of sessions addressed recent and ongoing global change assessments, the application of climate science to adaptive management (e.g., water, ecosystems, energy systems, coastal and air quality management), and the use of climate information in analyses of policy options.

Participants provided positive feedback on the opportunity to learn about CCSP's activities and exchange information with other scientists and decision makers. CCSP will use insights from the workshop to guide current and future CCSP programs, and intends to provide additional forums for future communication about this aspect of the program.

CLIMATE CHANGE TECHNOLOGY PROGRAM

In addition to laying a strong foundation in climate science, the United States is moving ahead on realistic technology options to meet the United Nations Framework Convention on Climate Change's (UNFCCC's) ultimate objective of stabilizing GHG atmospheric concentrations at a level that avoids dangerous human interference with the climate system.

The United States is leading the development of advanced technologies that have the potential to reduce, avoid, or sequester GHG emissions. CCTP[3] was created to coordinate and prioritize the U.S. government's investment in climate-related technology research, development, demonstration, and commercialization—which was about $3 billion in fiscal year 2006—and to further the President's National Climate Change Technology Initiative, a suite of discrete activities that, if successful, could advance technologies to avoid, reduce, or capture and store GHG emissions on a large scale.

CCTP developed its August 2005 *Vision and Framework for Strategy and Planning* (CCTP 2005b) and September 2006 *Strategic Plan* (CCTP 2006) to guide and prioritize the federal government's climate technology efforts. CCTP's strategic vision has six complementary goals: (1) reducing emissions from energy use and infrastructure; (2) reducing emissions from energy supply; (3) capturing and sequestering CO_2; (4) reducing emissions of other GHGs; (5) measuring and monitoring emissions; and (6) bolstering the contributions of basic science. Figure 8-1 provides a schematic roadmap for the technologies being pursued under these goals. A fuller explanation of these technologies is available in CCTP's *Research and Current Activities* (CCTP 2003) and *Technology Options for the Near and Long Term* (CCTP 2005a) reports.

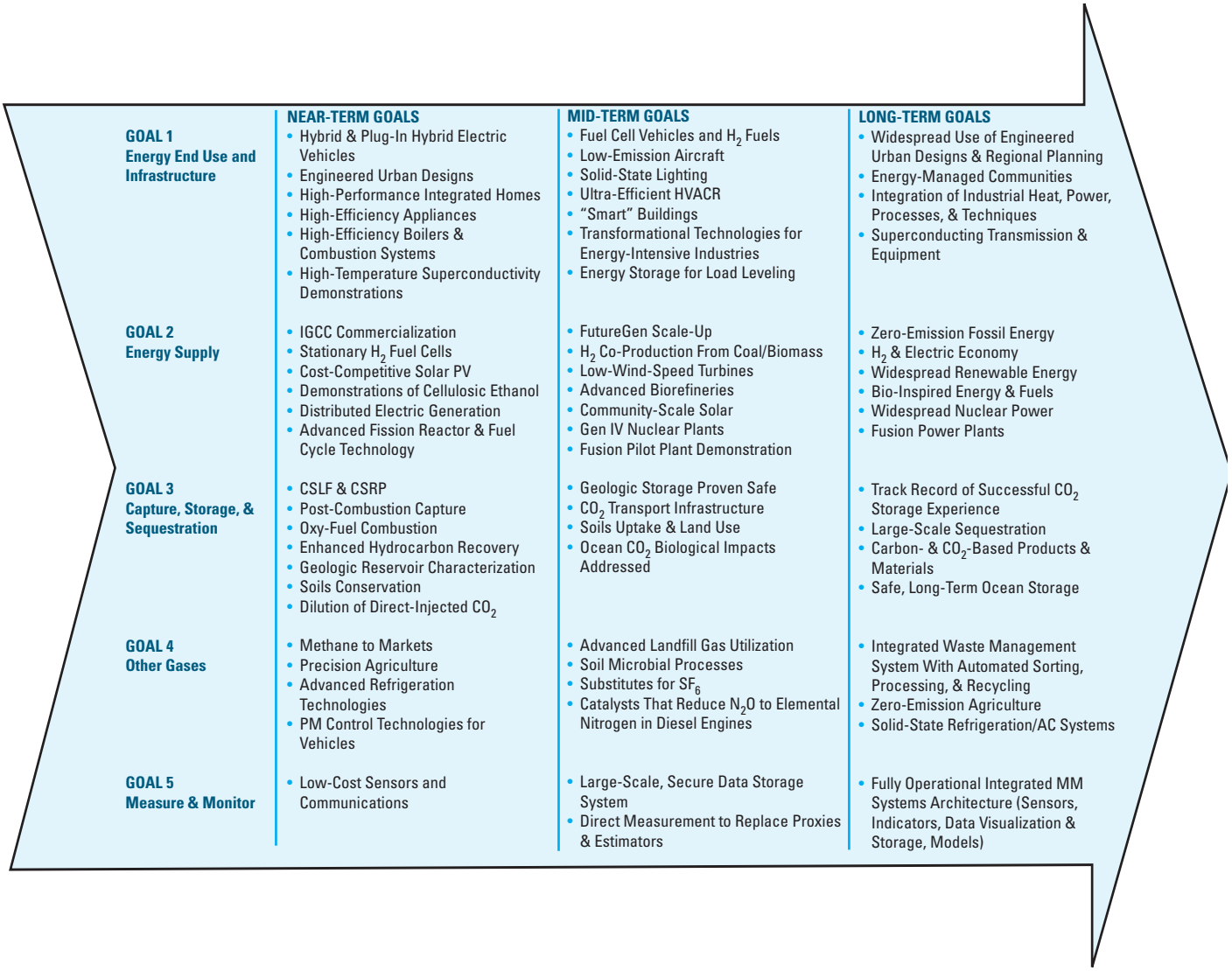
Energy Use and Infrastructure

Improving energy efficiency and reducing GHG emissions intensity in transportation, buildings, and industrial processes can significantly reduce overall GHG emissions. In addition, improving the infrastructure of the electricity transmission and distribution grid can reduce GHG emissions by making power generation more efficient and by providing greater grid access for wind and solar power.

Key research activities include the U.S. Department of Energy's (DOE's) Freedom CAR (Cooperative Automotive Research)[4] program, a cost-shared, government–industry partnership that is pursuing research and development in technologies needed to enable the mass production of affordable, practical hybrid vehicles, such as hydrogen-powered fuel-cell vehicles. The U.S. Environmental Protection Agency's Clean Automotive Technology[5] program is working on cost-effective automotive technologies that increase fuel efficiency and produce ultra-low pollution and GHG emissions. Advanced heavy-duty-vehicle technologies, zero-energy homes and commercial buildings, solid-state lighting, and high-temperature superconducting wires that virtually eliminate electricity transmission losses are other areas of research that could yield significant emission reductions.

[3] See <http://www.climatetechnology.gov>.
[4] See <http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html>.
[5] See <http://www.epa.gov/otaq/technology/>.

FIGURE 8-1 **Roadmap for Climate Change Technology Development**



Energy Supply

Fossil fuels, which emit CO_2 when burned, remain the world's energy supply of choice. Therefore, a transition to a low-carbon energy future would require the availability of cost-competitive low- or zero-carbon energy supply options. When combined with improved energy carriers, such as electricity and hydrogen, these options could offer the prospect of considerable reductions in GHG emissions.

Renewable energy includes a range of different technologies that can play an important role in reducing GHG emissions. The United States invests considerable resources in wind, solar photovoltaics, and biomass technologies. In fiscal year 2006, DOE and the U.S. Department of Agriculture (USDA) spent a combined $247.5 million on wind, solar, and biomass programs. Although the price competitiveness of many of these technologies has improved significantly, there still is a need to reduce their manufacturing, operating, and maintenance costs.

There will be a continuing need for portable, storable energy carriers for heat, power, and transportation. Hydrogen is an excellent energy carrier, generates no emissions when used in a fuel cell, and can be produced from diverse sources, including renewable, nuclear, and fossil fuel power (the last of which could be combined with carbon capture). President Bush's $1.2 billion Hydrogen Fuel Initiative[6] is exploring these production options, as well as the infrastructure needed to store and deliver hydrogen economically and safely. Current CCTP research is expected to make possible an industry decision to commercialize hydrogen fuel-cell vehicles in 2015, and possibly bring them to market by 2020.

Advanced fossil-based power and fuels is an area of special interest for the United States, because about half of the Nation's

[6] See <http://www.eere.energy.gov/hydrogenandfuelcells/presidents_initiative.html>.

electricity demand is generated from its vast coal reserves. FutureGen[7] is a 10-year, $1 billion government–industry collaboration to build the world's first emission-free, coal-fired power plant. This project, which includes India and the Republic of Korea, will incorporate the latest technologies in carbon sequestration, oxygen and hydrogen separation membranes, turbines, fuel cells, and coal-to-hydrogen gasification. Through this research, clean coal can remain part of a diverse, secure energy portfolio well into the future.

Concerns about resource availability, energy security, and air quality as well as climate change suggest a larger role for nuclear power as an energy supply choice. The Generation IV Nuclear Energy Systems Initiative[8] is investigating the next-generation reactor and fuel-cycle systems, which represent a significant leap in economic performance, safety, and proliferation resistance. One promising system being developed under the Nuclear Hydrogen Initiative[9] would pair very-high-temperature reactor technology with advanced hydrogen production capabilities that could produce both electricity and hydrogen on a scale to meet transportation needs. Complementing these programs is the Advanced Fuel Cycle Initiative—Advanced Burner Reactor,[10] which is developing advanced, proliferation-resistant nuclear fuel technologies that can improve the fuel cycle, reduce costs, and increase the safety of handling nuclear wastes.

Fusion energy[11] is a potential major new source of energy that, if successfully developed, could be used to produce electricity and possibly hydrogen. Fusion has features that make it an attractive option from both environmental and safety perspectives. However, the technical hurdles of fusion energy are very high, and with a commercialization objective of 2050, its impact will not be felt until the second half of the century.

Recent Initiatives

In his 2006 State of the Union Address, President Bush outlined plans for an Advanced Energy Initiative (AEI).[12] AEI aims to accelerate the development of advanced technologies that could change the way American homes, businesses, and automobiles are powered. AEI is designed to take advantage of technologies that with a little push could play a big role in helping to reduce both the Nation's use of foreign sources of energy and its pollution and GHG emissions. AEI includes greater investments in zero-emission coal-fired plants, solar and wind power, nuclear energy, better battery and fuel cell technologies for pollution-free cars, and cellulosic biorefining technologies for biofuels production. One component of AEI is the Global Nuclear Energy Partnership, a groundbreaking effort to develop a worldwide consensus on enabling expanded use of economical, carbon-free nuclear energy to meet growing electricity demand. This initiative is discussed in greater detail later in the Multilateral Research section, which begins on the following page.

Carbon Capture and Sequestration

Carbon capture and sequestration is a central element of CCTP's strategy, because for the foreseeable future, fossil fuels will continue to be the world's most reliable and lowest-cost form of energy. Thus, a realistic approach is to find ways to "sequester" the CO_2 produced when these fuels—especially coal—are used. The term *carbon sequestration* describes a number of technologies and methods to capture, transport, and store CO_2 or remove it from the atmosphere.

Advanced techniques to capture gaseous CO_2 from energy and industrial facilities and store it permanently in geologic formations are under development. DOE's core Carbon Sequestration Program[13] emphasizes technologies that capture CO_2 from large point sources and store the emissions in geologic formations capable of holding vast amounts of CO_2. In 2003, DOE launched a nationwide network of seven Regional Carbon Sequestration Partnerships[14] that include 40 states, four Canadian provinces, three Indian nations, and over 300 organizations. The partnerships' main focus is on determining the best approaches for sequestration in their regions. They are also examining regulatory and infrastructure needs. Small-scale validation testing of 35 sites involving terrestrial and geologic sequestration technologies began in 2005, and will continue until 2009.

Terrestrial sequestration—removing CO_2 from the atmosphere and sequestering it in trees, soils, or other organic materials—has proven to be a low-cost means for long-term carbon storage. The DOE-supported Carbon Sequestration in Terrestrial Ecosystems consortium provides research on mechanisms that can enhance terrestrial sequestration.[15] In addition, USDA operates the Greenhouse Gas Reduction Through Agricultural Carbon Enhancement Network at 30 locations around the country to measure and predict carbon sequestration and GHG emissions across a range of agricultural systems, soils, and climate zones.

Other Greenhouse Gases

A main component of the U.S. strategy is to reduce other GHGs, such as methane (CH_4), nitrous oxides (N_2O), sulfur hexafluoride (SF_6), and fluorocarbons.

Improvements in methods and technologies to detect and either collect or prevent CH_4 emissions from various sources—such as landfills, coal mines,

[7] See <http://fossil.energy.gov/programs/powersystems/futuregen/index.html>.
[8] See <http://gen-iv.ne.doe.gov>.
[9] See <http://nuclear.gov/hydrogen/hydrogenOV.html>.
[10] See <http://www.gnep.energy.gov/gnepAdvancedBurnerReactors.html>.
[11] See <http://www.sc.doe.gov/Program_Offices/fes.htm>.
[12] See <http://www.whitehouse.gov/stateoftheunion/2006/energy/index.html>.
[13] See <http://fossil.energy.gov/programs/sequestration/index.html>.
[14] See <http://fossil.energy.gov/programs/sequestration/partnerships/index.html>.
[15] Another option being explored is using biotechnology to enhance the ability of plants to take up CO_2, and thus sequester additional carbon.

natural gas pipelines, and oil and gas exploration operations—can prevent this GHG from escaping to the atmosphere. Reducing CH_4 emissions may also have a positive benefit in reducing local ozone problems, as CH_4 is a long-lived ozone precursor. In agriculture, improved management practices for fertilizer applications and livestock waste can reduce CH_4 and N_2O emissions appreciably.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and SF_6 are all high global warming potential (GWP) gases. HFCs and PFCs are used as substitutes for ozone-depleting chlorofluorocarbons and are used in or emitted during complex manufacturing processes. Advanced methods to reduce the leakage of, reuse, and recycle these chemicals and to use lower GWP alternatives are being explored.

Programs aimed at reducing particulate matter have led to significant advances in fuel combustion and emission control technologies to reduce U.S. black carbon aerosol emissions. Reducing emissions of black carbon, soot, and other chemical aerosols can have multiple benefits, including better air quality and public health and reduced radiative forcing.

Measuring and Monitoring

To meet future GHG emission measurement requirements, a wide array of sensors, measuring platforms, monitoring and inventorying systems, and inference methods are being developed. Many of the baseline measurement, observation, and sensing systems used to advance climate change science are being developed as part of CCSP. CCTP's efforts focus primarily on validating the performance of various climate change technologies, such as in terrestrial and geologic sequestration.

Basic Science

Basic scientific research is a fundamental element of CCTP. Tackling the dual challenges of addressing climate change and meeting growing world energy demand is likely to require discoveries and innovations that can shape the future in often unexpected ways. The CCTP framework aims to strengthen the basic research enterprise through strategic research that supports ongoing or projected research activities and exploratory research involving innovative concepts.

Multilateral Research

The United States believes that well-designed multilateral collaborations focused on achieving practical results can accelerate development and commercialization of new technologies. The United States has initiated or joined a number of multilateral technology collaborations in hydrogen, carbon sequestration, nuclear energy, and fusion that address many energy-related concerns (e.g., energy security, climate change, and environmental protection).

International Partnership for the Hydrogen Economy[16]

In November 2003, representatives from 16 governments gathered in Washington, D.C., to launch the International Partnership for the Hydrogen Economy (IPHE), a vehicle to coordinate and leverage multinational hydrogen research programs. IPHE will develop common recommendations for internationally recognized standards and safety protocols to speed market penetration of hydrogen technologies. An important aspect of IPHE is maintaining communications with the private sector and other stakeholders to foster public–private collaboration and address the technological, financial, and institutional barriers to hydrogen.

Carbon Sequestration Leadership Forum[17]

The Carbon Sequestration Leadership Forum (CSLF) is a multilateral U.S. initiative that provides a framework for international collaboration on sequestration technologies. Established at a June 2003 ministerial meeting held in Washington, D.C., CSLF consists of members from 22 governments representing both developed and developing countries.

The CSLF's main focus is assisting the development of technologies to separate, capture, transport, and store CO_2 safely over the long term; making carbon sequestration technologies broadly available internationally; and addressing broader issues relating to carbon capture and storage, such as regulation and policy. To date, CSLF has endorsed 17 international research projects, five of which involve the United States.

Generation IV International Forum[18]

In July 2001, under U.S. leadership, nine other countries and Euratom chartered the Generation IV International Forum (GIF), to fulfill the objective of the Generation IV Nuclear Energy Systems Initiative. GIF's goal is to develop a fourth generation of advanced, economical, safe, and proliferation-resistant nuclear systems that can be adopted commercially by 2030. Six technologies have been selected as the most promising candidates for future designs, some of which could be commercially ready by 2015. GIF countries are jointly preparing a collaborative research program to develop and demonstrate the projects.

ITER[19]

In January 2003, President Bush announced that the United States was joining the negotiations for the construction and operation of the international fusion experiment ITER. The goal of this proposed multilateral $5 billion collaborative project is to design and demonstrate a fusion energy production system. If successful, ITER

[16] See <http://www.iphe.net>. IPHE members include the United States, Australia, Brazil, Canada, China, European Commission, France, Germany, Iceland, India, Italy, Japan, New Zealand, Norway, Republic of Korea, Russian Federation, and United Kingdom.

[17] See <http://www.cslforum.org>. CSLF members include the United States, Australia, Brazil, Canada, China, Colombia, Denmark, European Commission, France, Germany, Greece, India, Italy, Japan, Republic of Korea, Mexico, Netherlands, Norway, Russian Federation, Saudi Arabia, South Africa, and United Kingdom.

[18] See <http://www.ne.doe.gov/genIV/neGenIV2.html>. GIF member countries include the United States, Argentina, Brazil, Canada, France, Japan, Republic of Korea, South Africa, Switzerland, and United Kingdom.

[19] See <http://www.iter.org>. ITER members include the United States, China, European Union, India, Japan, Republic of Korea, and Russian Federation.

will advance progress toward producing clean, abundant, commercially available fusion energy by the middle of the century. In November 2006, the seven ITER partners signed an agreement to construct the project.[20]

Global Nuclear Energy Partnership[21]

The Global Nuclear Energy Partnership (GNEP), a component of AEI, has two major goals: (1) expand carbon-free nuclear energy to meet growing electricity demand worldwide, and (2) promote nonproliferation objectives through the leasing of nuclear fuel to countries that agree to forgo enrichment and reprocessing. GNEP partner countries would consist of both fuel-supplier nations and reactor nations. Fuel-supplier nations would provide reliable nuclear fuel services to reactor nations through an independent nuclear fuel broker, such as the International Atomic Energy Agency.

SYSTEMATIC OBSERVATIONS

Long-term, high-quality observations of the global environmental system are essential for defining the current state of the Earth's system, its history, and its variability. This task requires both space- and surface-based observation systems. The term *climate observations* can encompass a broad range of environmental observations, including (1) routine weather observations, which, when collected consistently over a long period of time, can be used to help describe a region's climatology; (2) observations collected as part of research investigations to elucidate chemical, dynamic, biological, or radiative processes that contribute to maintaining climate patterns or to their variability; (3) highly precise, continuous observations of climate system variables collected for the express purpose of documenting long-term (decadal-to-centennial) change; and (4) observations of climate proxies, collected to extend the instrumental climate record to remote regions and back in time to provide information on climate change for millennial and longer time scales.

Satellite observations provide a unique prespective of the global integrated Earth system and are necessary for good global climate coverage. *In situ* observations are required for the measurement of parameters that cannot be estimated from space platforms (e.g., biodiversity, groundwater, carbon sequestration at the root zone, and subsurface ocean parameters). *In situ* observations also provide long time series of observations required for the detection and diagnosis of global change, such as surface temperature, precipitation and water resources, weather and other natural hazards, the emission or discharge of pollutants, and the impacts of multiple stresses on the environment due to human and natural causes.

One critical challenge to the Earth observation field is to maintain existing observation capabilities in a variety of areas. For example, maintaining the observational record of stratospheric ozone is essential in discerning the effects of climate change on the nature and timing of ozone recovery. Other key areas include radiative energy fluxes of the Sun and Earth, atmospheric carbon dioxide, and global surface temperature. Efforts to create a long-term record of global land cover, started by Landsat in the 1970s, are currently being prepared for the transition to a Landsat Data Continuity Mission (LDCM) being planned by the National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey.[22] The LDCM is expected to have a 5-year mission life with 10-year expendable provisions.

Planning continues on deploying the National Polar-orbiting Operational Environmental Satellite System (NPOESS). This satellite system is designed to monitor global environmental conditions, and to collect and disseminate data related to weather, atmosphere, oceans, land, and near-space environment. NPOESS will maintain a continuous global climate record for a subset of the environmental parameters measured on current U.S. research and operational satellites. The United States is currently evaluating the impacts of the current configuration, and is addressing options that could enhance future U.S. satellite-based climate monitoring. An NPOESS Preparatory Report mission is scheduled for launch in 2009, and the first NPOESS spacecraft is scheduled for launch in 2013.

To meet the long-term needs for the documentation of global changes, the United States integrates observations from both research and operational systems. The United States supports the need to improve global observing systems for climate, and to exchange information on national plans and programs that contribute to the global capacity in this area.

Providing for wide access to information from the Global Earth Observation System of Systems (GEOSS) for applications that benefit society has been a focus of efforts coordinated by the intergovernmental Group on Earth Observations (GEO) and the U.S. Group on Earth Observation (USGEO). An international framework for open access to GEOSS data was established, and a U.S. strategic plan was drafted to provide a basis for international cooperation. At the third Earth Observation Summit in February 2005, the United States joined nearly 60 countries and the European Commission in endorsing to a plan that, over the next 10 years, will revolutionize the understanding of Earth system processes. [23]

A key regional effort of GEOSS in the Western Hemisphere is known as GEOSS in the Americas. The vision of this effort is to build partnerships with countries and organizations in the Americas and the Caribbean to strengthen the ability to utilize each other's research and operational Earth observations. The first significant GEOSS in the Americas project involved the shifting of the GOES-10 satellite in 2006 to a new orbit, to greatly improve environmental satellite coverage of the Western Hemisphere, especially over South America. By

[20] The seven ITER partners are the European Union, India, Japan, People's Republic of China, Republic of Korea, Russian Federation, and United States.
[21] See <http://www.gnep.energy.gov>.
[22] See <http://landsat.gsfc.nasa.gov/>.
[23] For more details, see <http://earthobservations.org>.

significantly enhancing satellite detection of such natural hazards as severe storms, floods, drought, landslides, and wildfires, the shift will help protect lives and property in both South America and the United States, and will allow for improved prediction, response, and follow-up and expanded understanding of Earth system processes.[24]

Potential benefits of Earth observations were detailed in the IEOS 10-year strategic plan that covered climate and eight other related areas—agriculture, disasters, ecology, energy, health, integration, ocean resources, water resources, and weather (IWGEO and NSTC/CENR 2005). Similarly, the CCSP *Strategic Plan* (CCSP and SGCR 2003a) has identified several overarching questions for observing and monitoring the climate system, such as: *How can we provide stewardship for open access to integrated data and products with sufficient accuracy and precision to address climate and associated global changes?*

Documentation of U.S. Climate Observations

As part of its continuing contributions to systematic observations in support of climate monitoring, the United States submitted *The United States Detailed National Report on Systematic Observations for Climate* to the UNFCCC Secretariat on September 6, 2001 (U.S. DOC/NOAA 2001). The report documents the U.S. systematic climate observing program and includes information on *in situ* atmospheric observations, *in situ* oceanographic observations, *in situ* terrestrial observations, and satellite-based observations. The report attempted to cover all relevant observation systems and is representative of the larger U.S. effort to collect environmental data. The United States supports a broad network of *in situ* global atmospheric, ocean, and terrestrial observation systems, as well as a large number of remote-sensing satellite platforms that are essential to climate monitoring.

In Situ *Atmospheric Observations*

The United States supports 75 stations in the Global Climate Observing System (GCOS) Surface Network (GSN), 21 stations in the GCOS Upper Air Network (GUAN), and 4 stations in the Global Atmospheric Watch (GAW). These stations are distributed geographically as prescribed in the GCOS and GAW network designs. The data (metadata and observations) from these stations are shared according to GCOS and GAW protocols.

Since publishing its last report to the UNFCCC, the United States has begun fielding and commissioning a system known as the Climate Reference Network (CRN). The CRN is designed to answer the question: *How has the U.S. climate changed over the past 50 years at national, regional, and local levels?* Since 2002, 74 CRN stations have been commissioned out of a planned 110 stations.[25]

The U.S. GCOS program supports a number of climate observing systems and projects in developing nations. In 2002, there were 20 nontransmitting GUAN stations around the globe. Through focused projects, the number of nontransmitting stations has dropped to 6. The GCOS program continues to ensure the long-term sustainability of all stations through the establishment of regional technical and maintenance support centers for southern and eastern Africa, the Caribbean, and the Pacific Islands. Related to this capacity-building activity, the program will be supporting an intensive upper-air campaign as part of the African Monsoon Multidisciplinary Analysis, with the installation of a new hydrogen generator at the upper-air site in Dakar, Senegal.

While it is difficult to list all observing campaigns and systems, several others should be noted for their global climate significance. The Southern Hemisphere ADditional OZonesondes (SHADOZ) provides a consistent dataset from balloon-borne ozonesondes for ground verification of satellite tropospheric ozone measurements at 12 sites across the tropical and subtropical regions of the southern hemisphere.[26] Another key system along these lines is the Aerosol Robotic NETwork (AERONET), which is a federation of ground-based, remote-sensing aerosol networks established in part by NASA and France's Centre Nationale de Recherche Scientifique (CNRS).[27] AERONET provides a long-term, continuous, and readily accessible public domain database of aerosol optical properties for research and characterization of aerosols and for validation of satellite retrievals. AERONET provides synergy with other databases, along with a series of globally distributed observations of spectral aerosol optical depth, inversion products, and precipitable water in diverse aerosol regimes.

The collaborative effort between NASA's Advanced Global Atmospheric Gases Experiment (AGAGE) and NOAA's Flask Monitoring Network has been instrumental in measuring the composition of the global atmosphere continuously since 1978. The AGAGE is distinguished by its capability to measure globally and at high frequency most of the important gases in the *Montreal Protocol* to protect the ozone layer and almost all of the significant non-CO_2 gases in the *Kyoto Protocol* to mitigate climate change. This key climate monitoring activity demonstrates NASA's and NOAA's significant collaborative research efforts.[28]

The primary goal of the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) is to provide the infrastructure needed for studies investigating atmospheric processes in several climatic regimes and for climate model development and evaluation. The ACRF consists of three stationary facilities, an ARM Mobile Facility (AMF), and the ARM Aerial Vehicles Program (AAVP). The stationary sites provide scientific test beds in three climatically significant regions (mid-latitude, polar, and tropical), and the AMF provides a capability to address high-priority scientific questions in

[24] See <http://www.strategies.org/EOPA.html>.
[25] See <http://www.ncdc.noaa.gov/oa/climate/uscrn>.
[26] See <http://croc.gsfc.nasa.gov/shadoz/>.
[27] See <http://aeronet.gsfc.nasa.gov/data_frame.html>.
[28] See <http://agage.eas.gatech.edu/> and <http://www.esrl.noaa.gov/>.

regions other than the stationary sites. The AAVP provides a capability to obtain *in situ* cloud and radiation measurements that complement the ground measurements. Data streams produced by the ACRF will be available to the atmospheric community for use in testing and improving parameterizations in global climate models. The AMF was deployed in Niamey, Niger, in 2006 measuring radiation, cloud, and aerosol properties during the monsoon and dry seasons.

In Situ *Ocean Observations*

The climate requirements of the Global Ocean Observing System (GOOS) are the same as those for GCOS. Also like GCOS, GOOS is based on a number of *in situ* and space-based observing components. The United States supports the Integrated Ocean Observing System's surface and marine observations through a variety of components, including fixed and surface-drifting buoys, subsurface floats, and volunteer observing ships. It also supports the Global Sea Level Observing System through a network of sea level tidal gauges.

The United States currently provides satellite coverage of the global oceans for sea-surface temperatures, surface elevation, ocean-surface vector winds, sea ice, ocean color, and other climate variables. The first element of the climate portion of GOOS, completed in September 2005, is the global drifting buoy array, which is a network of 1,250 drifting buoys measuring sea-surface temperature and other variables as they flow in the ocean currents.

Continued upgrading of the Global Sea Level Observing System (GLOSS) tidal gauge network from 43 to 170 stations is planned for 2006–10. Ocean carbon inventory surveys in a 10-year repeat survey cycle help determine the anthropogenic intake of carbon into the oceans. Plans for advancement of the global Tropical–Atmosphere–Ocean (TAO) network of ocean buoys include an expansion of the network into the Indian Ocean (the Pacific Ocean has a current array of 70 TAO buoys). During 2005-07, 8 new TAO buoys were installed in the Indian Ocean in collaboration with partners from India, Indonesia, and France. Plans call for a total of 39 TAO buoys in the Indian Ocean by 2013. These moorings will enhance the tropical networks currently monitoring above-surface, surface, and subsurface conditions in the Pacific and Atlantic Oceans. As of the end of 2006, 57 percent of the GOOS suite of ocean climate observing platforms had been fielded; the full system of ocean climate sensors is scheduled for completion by 2010.

The Integrated Ocean Observing System (IOOS) is the U.S. coastal observing component of GOOS. IOOS is envisioned as a coordinated national and international network of observations, data management, and analyses that systematically acquires and disseminates data and information on past, present, and future states of the oceans. A coordinated IOOS effort is being established by NOAA via a national IOOS Program Office co-located with the Ocean.US consortium of offices consisting of NASA, NOAA, the National Science Foundation, and the U.S. Navy.[29] The IOOS observing subsystem employs both remote and *in situ* sensing. Remote sensing includes satellite-, aircraft-, and land-based sensors; power sources; and transmitters. *In situ* sensing includes platforms (ships, buoys, gliders, etc.); *in situ* sensors; power sources; sampling devices; laboratory-based measurements; and transmitters.

In Situ *Terrestrial Observations*

For terrestrial observations, GCOS and the Global Terrestrial Observing System (GTOS) have identified permafrost thermal state and permafrost active layer as key variables for monitoring the state of the cryosphere. The United States operates a long-term "benchmark" glacier program to intensively monitor climate, glacier motion, glacier mass balance, glacier geometry, and stream runoff at a few select sites. The data collected are used to understand glacier-related hydrologic processes and improve the quantitative prediction of water resources, glacier-related hazards, and the consequences of climate change. Long-term, mass-balance monitoring programs have been established at three widely spaced U.S. glacier basins that clearly sample different climate-glacier-runoff regimes.

SNOTEL and SCAN Networks—The SNOTEL (SNOpack TELemetry) and SCAN (Soil Climate Analysis Network) monitoring networks provide automated comprehensive snowpack, soil moisture, and related climate information designed to support natural resource assessments. SNOTEL operates more than 660 remote sites in mountain snowpack zones of the western United States. SCAN, which began as a pilot program, now consists of more than 120 sites. These networks collect and disseminate continuous, standardized soil moisture and other climate data in publicly available databases and climate reports. Uses for these data include inputs to global circulation models, verifying and ground truthing satellite data, monitoring drought development, forecasting water supply, and predicting sustainability for cropping systems.

Polar Climate Observations—Polar climate observations will continue to be a focus of U.S. activities as preparations are made for the International Polar Year beginning in 2007. Currently, the United States maintains soil-moisture climate stations in both Alaska and Antarctica, and plans to increase efforts on observations of the Arctic atmosphere, sea ice, and ocean. Working with a number of Arctic nations via the International Arctic Systems for Observing the Atmosphere (IASOA), the United States will deploy and/or participate in a number of observing activities to produce a higher-resolution characterization of clouds and aerosols and of both incoming and outgoing radiation, to provide the high-quality records needed to detect climate change and to improve calibration of broad-scale satellite observations in the Arctic. For example, through the IASOA process, the United States will be working

[29] See <http://www.ocean.us/>.

with its international partners in establishing a super-site climate observatory in the Russian Arctic in Tiksi, north of the Arctic Circle at latitude 71.50° North.

The AmeriFLUX Network—The AmeriFLUX network endeavors to establish an infrastructure for guiding, collecting, synthesizing, and disseminating long-term measurements of CO_2, water, and energy exchange from a variety of ecosystems. Its objectives are to collect critical new information to help define the current global CO_2 budget, enable improved projections of future concentrations of atmospheric CO_2, and enhance the understanding of carbon fluxes, net ecosystem production, and carbon sequestration in the terrestrial biosphere.

North American Carbon Program—A major focus of the U.S. CCSP, the North American Carbon Program measures and studies the sources and sinks of CO_2, CH_4, and CO in North America and in adjacent ocean regions.

Space-Based Observations

Space-based, remote-sensing observations of the atmosphere–ocean–land system have evolved substantially since the early 1970s, when the first operational weather satellite systems were launched. Over the last decade satellites have proven their observational capability to accurately monitor nearly all aspects of the total Earth system on a global basis. Currently, satellite systems monitor the evolution and impacts of El Niño and La Niña, weather phenomena, natural hazards, and vegetation cycles; the ozone hole; solar fluctuations; changes in snow cover, sea ice and ice sheets, ocean surface temperatures, and biological activity; coastal zones and algal blooms; deforestation and forest fires; urban development; volcanic activity; tectonic plate motions; aerosol and three-dimensional cloud distributions; water distribution; and other climate-related information.

A number of U.S. satellite operational and research missions form the basis of a robust national remote-sensing program that fully supports the requirements of GCOS (U.S. DOC/NOAA 2001). These include instruments on the Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES), the series of Earth Observing Satellites (EOS), the Landsats 5 and 7, the Total Ozone Mapping Spectrometer satellite, and the Jason satellite measuring sea-surface height, winds, and waves. Additional satellite missions in support of GCOS include (1) the Active Cavity Radiometer Irradiance Monitor for measuring solar irradiance; (2) the EOS-Terra, Aqua, and Aura series; (3) QuickSCAT; (4) the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) for studying ocean and productivity, as well as aerosols; (5) the Shuttle Radar Topography Mission; and (6) the Tropical Rainfall Measuring Mission for measuring rainfall, clouds, sea-surface temperature, radiation, and lightning. A major upgrade to the GOES system, known as GOES-R, is under development, with a first launch scheduled for late 2012.

Also, several new missions will be launched during the next few years: (1) the Orbiting Carbon Observatory mission will measure CO_2 (2008 launch); (2) Glory mission will measure black carbon soot and other aerosols, as well as total solar irradiance (2008 launch); (3) the altimetry Ocean Surface Topography mission will provide sea-surface heights for determining ocean circulation, climate change, and sea level rise (2008 launch); (4) Aquarius will measure global sea surface salinity (2009 launch); and (5) the Global Precipitation Measurement mission will monitor worldwide precipitation (2012 launch).

Some recent missions since the last report to the UNFCCC include:

- The Ice, Cloud, and Land Elevation Satellite (ICESat), launched in 2003, has been measuring surface elevations of ice and land, vertical distributions of clouds and aerosols, vegetation-canopy heights, and other features with unprecedented accuracy and sensitivity. The primary purpose of ICESat has been to acquire time series of ice-sheet elevation changes for determining the present-day mass balance of the ice sheets, to study associations between observed ice changes and polar climate, and to improve estimates of the present and future contributions to global sea level rise.
- The Solar Radiation and Climate Experiment (SORCE) satellite, launched in 2003, is equipped with four instruments that measure variations in solar radiation much more accurately than previous measurements and observe some of the spectral properties of solar radiation for the first time.
- The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and CloudSat satellites were successfully launched in April 2006. CALIPSO and CloudSat are highly complementary and together will provide new, three-dimensional perspectives of how clouds and aerosols form, evolve, and affect weather and climate. Both Calipso and CloudSat fly in formation as part of the NASA A-Train constellation (e.g., along with Aqua, Aura, and the French PARASOL spacecraft), providing the benefits of near simultaneity and, thus, the opportunity for synergistic measurements made with complementary techniques.

NASA's Gravity Recovery and Climate Experiment (GRACE) twin satellites celebrated their fifth anniversary on orbit in March 2007, completing a successful primary mission that has provided improved estimates of the Earth's gravity field on an ongoing basis. In conjunction with other data and models, GRACE has provided observations of terrestrial water storage changes, ice-mass variations, ocean bottom pressure changes, and sea level variations.

Data Management

Data management is an important aspect of any systematic observing effort. U.S. agencies have separate and unique mandates for climate-focused and -related systematic observations, and for the attendant data processing, archiving, and use of the important information from these observing systems.

Cooperative efforts by CCSP and USGEO agencies are moving toward

providing integrated and more easily accessible Earth observations. Currently operating CCSP systems for data management and distribution highlighted in the 2007 *Our Changing Planet* report include NASA's Global Change Master Directory and Earth Observing System Data and Information System, and DOE's Carbon Dioxide Information Analysis Center (CCSP and SGCR 2006a). NOAA's National Climatic Data Center's (NCDC's) Climate Data Online site provides climate data from multiple stations around the world. Plans for 2007 and 2008 include the International Polar Year (IPY) participation through a focus on polar climate observations via NCDC's World Data Center for Meteorology.[30] Data management for IPY is coordinated among multiple U.S. agencies and throughout the world.

U.S. agencies and participants in CCSP and USGEO are working with their partners in Earth observation for climate action on local, state, regional, and national levels and in government, academia, and the private sector.

Finally, efforts are being explored to improve climate data integration in the Pacific Islands region and produce more useful, end-user-driven climate products. The Pacific Region Integrated Data Enterprise (PRIDE), currently underway in Hawaii, is efficiently using existing resources via a newly created NOAA Integrated Data and Environmental Applications (IDEA) Center, which is developing more customer-focused, integrated environmental products. Operating under the auspices of NOAA's NCDC, the IDEA Center is partnering with academic institutions and other federal and local agencies in the region to provide information on (1) issues related to Pacific islands, including past, current, and future trends in patterns of climate- and weather-related extreme events (e.g., tropical cyclones, flooding, drought, and ocean temperature extremes); (2) their implications for key sectors of the economy, such as agriculture, tourism, and fisheries; and (3) options for coastal communities and marine ecosystem managers to adapt to and manage the effects of variable and changing environmental conditions.[31]

International and Regional Support and Cooperation for Sustained Climate Observations

The Regional Implementation Workshop, initiated by GCOS in response to Decision 6/CP.5 of the UNFCCC, expanded on the Secretariat of the Pacific Regional Environment Program's needs analysis. Held in Apia, Samoa, in August 2000 with the support and active participation of Australian and U.S. experts, the workshop provided the basis for development of a Pacific Island-GCOS (PI-GCOS) program[32] to implement high-priority actions required to restore and improve observing systems in the region, to effectively monitor and detect trends and changes in the region's climate. The U.S. GCOS Program Office at NOAA's NCDC supports and contributes resources to the PI-GCOS effort.

Since 2002, the United States has entered into a number of important bilateral climate agreements, funding projects with Australia, China, New Zealand, and South Africa. These wide-ranging projects deal with climate prediction, ocean observation, stratospheric detection, water vapor measurements, capacity building and training, and communication of information, and focus the attention and resources of these countries on developing a more sustainable and robust GCOS program.

Finally, the transition of the Global Observing System Information Center (GOSIC)[33] from a developmental activity at the University of Delaware to an operational global data facility at NOAA's NCDC was completed on behalf of and with the concurrence of the global observing community in October 2006. GOSIC provides information, and facilitates easier access to data and information produced by GCOS, GOOS, and GTOS and their partner programs. The distributed nature of this vast system of global and regional data and information systems is best served by this single entry point for users. GOSIC provides explanations of the various global data systems, as well as an integrated overview of the myriad global observing programs, which includes on-line access to their data, information, and services. GOSIC offers a search capability across international data centers, to enhance access to a worldwide set of observations and derived products.

[30] See <http://www.ncdc.noaa.gov/oa/wdc/>.
[31] See <http://www.apdrc.soest.hawaii.edu/PRIDE>.
[32] See <http://pi-gcos.org>.
[33] For more details, see <http://gosic.org>.

9 Education, Training, and Outreach

Climate change education, training, and outreach have continued to expand since the last *U.S. Climate Action Report* was released in 2002. Federal programs support formal educational initiatives ranging from K-12 classroom curriculum to undergraduate, graduate, and postdoctoral research, and informal education conducted in museums, parks, nature centers, zoos, and aquariums across the country. Educators can also access extensive on-line educational global change resources, such as the sample federal websites highlighted in Table 9-1 at the end of this chapter.

Efforts by state and local governments, universities, schools, and nongovernmental organizations (NGOs) are essential complements to federal programs that educate industry and the public regarding climate change. State environment and energy agencies provide teacher training workshops, often in cooperation with universities and local utility companies; local school systems institute climate change curricula and activities at the middle and high school levels; universities are joining forces with NGOs to educate staff and students about the importance of energy efficiency and are instituting new, sustainable practices on campuses across the country. From wildlife conservation groups (e.g., National Wildlife Federation, World Wildlife Fund, Izaak Walton League, and Federation of Fly Fishers), to science-based organizations (e.g., American Meteorological Society, Union of Concerned Scientists), to energy-oriented groups (e.g., Alliance to Save Energy), a variety of NGOs conduct workshops and surveys, produce brochures and kits, and write media articles to alert the public to the science underlying, impacts of, and possible solutions to climate change.

Industry is also beginning to play a role in education, training, and outreach. Several corporations have contributed to the National Park Service's efforts to communicate energy efficiency messages; various electric utilities conduct education forums to educate the public about the sources and choices of electrical power in this country and the need for energy efficiency in today's world; oil companies advertise and sponsor conferences to make people aware of alternative energy sources and the possible impacts of the choices we make.

Because of these efforts, the American public is better informed about climate change and better equipped to adjust their lifestyles to enhance the sustainability of planet Earth.

FEDERAL AGENCY EDUCATION AND OUTREACH ACTIVITIES

Several federal agencies provide state and local governments, industry, NGOs, and the public with information about national and global climate change research and risk assessments studies, U.S. mitigation activities, and policy developments. They work both independently and in partnership with other agencies, NGOs, and industry toward the common goal of increasing awareness about the potential environmental and societal challenges posed by climate change.

U.S. Agency for International Development

The U.S. Agency for International Development's (USAID's) Global Climate Change Program incorporates climate change considerations into development projects. A significant part of this program involves building the capacity of local partners to understand how climate change issues affect their ability to achieve their development goals.

Global Climate Change Program

The Global Climate Change Program provides a resource for learning more about USAID's climate change activities in more than 40 developing and transition countries. The program's Publications and Outreach section includes sector overviews, such as Clean Energy Technology, Land Use and Forestry, Adapting to Climate Variability and Change, Capacity Building, and Climate Science for Decision Making. The program also provides publications focusing on climate change and individual regions, and highlights the climate change activities undertaken in various countries where USAID maintains climate change portfolios, including training, education, and outreach efforts.

Climate Partnerships

USAID places particular emphasis on partnerships with the private sector and on working with other U.S. government agencies, local and national authorities, communities, and NGOs to create alliances that build on each other's relative strengths. Bringing together a diverse range of stakeholders helps avoid unnecessary duplication and lays the foundation for a sustained, integrated approach. Through training, tools, and other means of capacity building, USAID helps developing countries and countries with economies in transition address climate-related concerns as a part of their development goals.

Mexico Landfill Gas Model—An example of these climate partnerships is USAID's collaboration with the U.S. Environmental Protection Agency (EPA) and several Mexican government agencies to help landfill owners and operators in Mexico evaluate the feasibility and potential benefits of collecting and using landfill gas for energy recovery. This effort resulted in the development of the Mexico Landfill Gas Model, a training workshop, and a guidance manual.

Global Partnerships

Since its inception, USAID has worked in cooperation with U.S. and international partners to improve conditions for people around the world. While these partnerships have long been key to USAID's success, this strategy has never been more important than now. USAID is committed to an approach that recognizes and incorporates the efforts of partnership and private giving, focusing on grassroots support, local ownership, sustainability, and accountability.

U.S. Department of Agriculture

As the U.S. Department of Agriculture's (USDA's) chief intramural scientific research body, the Agricultural Research Service (ARS) is responsible for research on the impacts of agricultural practices on potential climate change or disruptions and vice versa. Although ARS has no formal educational mechanism to disseminate research information to the general public, it employs a number of less formal means to communicate and make use of research advances.

All scientific research publications are submitted with an Interpretive Summary that is used for timely news releases. In addition, through collaboration with university scientists, climate change research information is provided to state and county cooperative extension agencies for release to identified producers. Also, all agency field locations publish informative brochures that describe their work and the impact of the research findings on stakeholders' interests.

Table 9-1 lists websites that provide additional information about ARS's Global Change Program and research magazine, the Global Change Program Office's activities, and the Natural Resources Conservation Service's work on managing carbon sequestration and reducing greenhouse gas emissions.

U.S. Department of Energy

The U.S. Department of Energy (DOE) supports numerous education and outreach initiatives focused on increasing energy efficiency and reducing greenhouse gas emissions. Some of these initiatives are outlined below and in Table 9-1.

Energy Efficiency Initiatives

Energy Savers—This program and public awareness campaign educates consumers, homeowners, and businesses on smart energy use and how to cut energy bills.

Energy Hog—This national public service advertising campaign helps children and their parents learn about energy-efficient behavior.

Building Technologies Program—This program offers a wide range of information on reducing energy consumption in homes and other buildings, which account for roughly 40 percent of energy use.

Building Toolbox—This comprehensive guide to designing, constructing, or renovating more efficient, affordable buildings includes software tools to help researchers, designers, architects, engineers, builders, code officials, and others evaluate and rank potential energy efficiency technologies and renewable energy strategies.

Home Energy Saver—Part of the joint DOE/EPA ENERGY STAR program, this initiative is designed to help consumers identify the best ways to save energy in their homes and find the resources to realize those savings.

Carbon Dioxide Information Analysis Center

This center, which includes the World Data Center for Atmospheric Trace Gases, is DOE's primary center for global change data and information analysis.

National Institute for Global Environmental Change

This DOE-funded institute conducts research on global climate change in six U.S. regions—the Great Plains, Midwest, Northeast, South Central, Southeast, and West; integrates and synthesizes information to help decision makers and communities better respond to regional-scale or ecosystem-scale

effects of climate change; and educates the public on climate change and energy-related environmental risks.

Office of Fossil Energy, National Energy Technology Lab, Keystone Center

DOE's Office of Fossil Energy and the National Energy Technology Lab are working with the Keystone Center of Keystone, Colorado, to conduct outreach, risk communication, stakeholder efforts, and focus groups to better understand community concerns related to carbon sequestration. The Keystone Center hosts a teacher training institute focusing on a climate change curriculum developed under a grant from DOE. Its staff attend regional and national meetings to present overviews of the curriculum to teachers across the country.

Global Change Education Program

DOE's Global Change Education Program continues to support three coordinated components aimed at providing both research and educational support to postdoctoral scientists, graduate students, faculty, and undergraduates at minority colleges and universities, through the Summer Undergraduate Research Experience (SURE), Graduate Research Environmental Fellowships (GREF), and the Significant Opportunities in Atmospheric Research and Science (SOARS) program.

U.S. Department of the Interior

National Park Service

As the steward of the world's foremost system of national parks, the National Park Service (NPS) is responsible for preserving and protecting the significant resources within the parks for the enjoyment of future generations. Recognizing its role as the model for national park systems around the world, NPS has increased its support of education on climate change and environmental stewardship through several innovative programs.

Sustainability Initiative—Through a combination of interpretive talks, signage, brochures, fact sheets, and other informational materials and programs, NPS is educating visitors about its efforts to ensure the sustainability of the national park system.

Greening of the National Park Service—NPS conserves energy and incorporates renewable energy resources into the park system to save money, to protect the parks' natural resources, and to educate the public about creating environmentally friendly facilities. Park visitors learn about NPS's "greening" activities through fact sheets, brochures, and on-site signage.

Climate Friendly Parks—NPS and EPA have joined forces to conduct the Climate Friendly Parks program. NPS is "leading by example" in mitigating climate change and air quality impacts in the parks by implementing action plans to reduce greenhouse gas emissions in the parks and providing a model to visitors on how to reduce energy consumption and emissions in their communities. The action plans are based on greenhouse gas emission inventories that quantify their baseline activities in several areas, including facility management, fleet management, visitor transportation, and waste management. The parks commit to educating park visitors and the community on the importance of reducing emissions and saving energy, and how these actions may help reduce harmful impacts on the parks. NPS communicates success stories from its parks' mitigation work through its creative labeling of energy-efficient projects in the parks, interpretive programs in the parks and in the communities, educational programs in schools, and wayside exhibits.

U.S. Geological Survey

As the Nation's largest water, Earth, and biological science and civilian mapping agency, the U.S. Geological Survey (USGS) collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. The agency's diversity of scientific expertise enables it to carry out large-scale, multidisciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers.

The USGS and Science Education—USGS provides scientific information to educate the public about natural resources, natural hazards, geospatial data, and quality-of-life issues. Educational resources include lesson plans and maps to assist teachers in communicating the concepts of global change.

Earth Surface Dynamics Program—USGS global change research activities strive to achieve a whole-system understanding of the interrelationships among Earth surface processes, ecological systems, and human activities. USGS work in the Earth Surface Dynamics Program focuses on understanding the likely consequences of climate change, especially by studying how climate has changed in the past.

U.S. Department of Transportation

Transportation is the fastest-growing U.S. source of greenhouse gases. Additionally, climate change may affect U.S. transportation systems through more frequent weather disruptions, changes in infrastructure life, rising sea levels, and other impacts. The U.S. Department of Transportation (DOT) has developed programs to address these issues.

Center for Climate Change and Environmental Forecasting

The center is the focal point of DOT technical expertise on transportation and climate change. Through strategic research, policy analysis, partnerships, and outreach, the center focuses on activities designed to reduce transportation-related greenhouse gases and to mitigate the effects of global climate change on the transportation network.

It All Adds Up to Cleaner Air

Developed and guided by the Federal Highway Administration, the Federal Transit Administration, and EPA, this initiative is a multilevel public education and partnership-building program to inform the public about the connections between their transportation choices, traffic congestion, and air pollution through television, radio, and print public service announcements. The program encourages people to take simple, convenient actions that can make a difference in traffic congestion and air quality when practiced on a wide scale, such as trip chaining

(combining trips), car maintenance, and alternative modes of transportation.

The campaign's messages were designed to increase public awareness of the connection between travel behavior and air quality, with a focus on reducing criteria air pollutants from motor vehicles. Improved transportation choices also produce an important ancillary benefit of reducing greenhouse gas emissions.

U.S. Environmental Protection Agency

EPA supports numerous climate change outreach and education initiatives for various audiences, helping them better understand climate change, its implications, and programs led or supported by the Agency. EPA also provides useful tools to help individuals and organizations identify measures they can take to reduce greenhouse gas emissions. Following are EPA education, training, and outreach efforts targeted to business and industry, the general public, and educators and students, and information about EPA training for select leaders, educators, and technicians, sea level rise outreach, and technical assistance to state and local governments.

Business and Industry Outreach

EPA has actively engaged business and industry on climate change-related issues, with a goal of working together to reduce greenhouse gas emissions and improve corporate operational efficiency. *ENERGY STAR*, the Green Power Partnership Program, Climate Leaders, the SmartWay Transport Partnership, the Landfill Methane Outreach Program, and the international Methane to Markets Partnership are all examples of the many hallmark public–private partnership programs that EPA leads. These partnerships and programs, among others, provide businesses and consumers with tools, technical assistance, information and cost-effective ways to save energy, foster the use of clean energy, reduce greenhouse gas emissions, and promote energy security and efficiency at home and abroad.

General Public Outreach

The Climate Change website supports EPA's mission to protect human health and the environment by presenting accurate, accessible, understandable information on climate change and global warming to communities, individuals, businesses, public officials, governments, and other interested parties. The site features climate science, emissions data, impact assessment summaries, U.S. policy information, and suggested actions that individuals and other interested parties can take to reduce greenhouse gas emissions.

Resources for Educators and Students

Climate Change, Wildlife and Wildlands Toolkit for Teachers and Interpreters—EPA led a partnership effort with NPS and the U.S. Fish and Wildlife Service to develop a climate change educational toolkit for classroom teachers and natural resource interpreters. The kit contains fact sheets, a short video, and other presentation materials that investigate the links between climate change and changes to habitat, ecosystems, wildlife, and public lands, including national parks and wildlife refuges.

Global Warming Wheel Card Classroom Activity Kit—This tool helps teachers educate students in grades 6 through 8 about the causes and potential impacts of global warming. Centered on the hand-held wheel card that students use to estimate household carbon dioxide emissions, the kit encourages students to think about ways to reduce their personal, family, school, and community contributions to the greenhouse effect.

Students' Energy Manual—EPA worked with Harvard University to develop an online manual designed to help members of other campus communities initiate student internship programs aimed at improving energy efficiency, reducing greenhouse gas emissions, and producing economic and educational benefits as well.

Topic-Specific Brochures—EPA has produced several brochures to educate specific audiences about particular topics relevant to possible climate change impacts in the United States. Those brochures include *Climate Change and Birds*, *Climate Change and Cold-Water Fish*, *Climate Change and Public Lands*, and *Climate Change and Coral Reefs*. EPA is currently revising all of the brochures to reflect the latest scientific research.

Training of Select Leaders, Educators, and Technicians

EPA responds to many requests to train educators to more effectively use EPA-produced kits in their classrooms, to help other government agencies educate their staff to interact with the public on climate change issues, and to teach students how they can help reduce greenhouse gas emissions. EPA also shares information with international parties on technical issues, including greenhouse gas inventory methodologies and practices, economic modeling, analysis of the co-benefits of simultaneous reductions in greenhouse gases and conventional air pollutants, technology assessments, and preparation of National Communications for the United Nations Framework Convention on Climate Change.

Sea Level Rise Outreach

EPA supports a number of projects to provide information to stakeholders who wish to take timely measures in anticipation of sea level rise. Planning scenario mapping projects inform coastal planners about sea level rise. Informational brochures about the risk of sea level rise, including maps of states with coastal land, illustrate which areas are likely to be protected against rising seas and which are likely to flood. These efforts inform dialogue within communities about how to prepare for sea level rise.

State and Local Technical Assistance

To enable state and local governments to quantify and reduce greenhouse gas emissions, EPA has developed tools in cooperation with its partners, and offers technical assistance to help determine the emissions implications of a range of policy options. These quantification tools include the Clean Air and Climate Protection Software and the State Greenhouse Gas Inventory Tool.

States have made great progress in implementing innovative and cost-effective energy efficiency and renewable energy programs and policies that achieve multiple

benefits, including reducing greenhouse gases. EPA technical assistance and guidance help states and municipalities adopt clean energy strategies and then share these successes with their peers through EPA-sponsored technical forums for state policymakers and other information-exchange opportunities.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration (NASA) conducts education, training, and public awareness on climate change, using NASA's observational, research, and modeling assets.

Primary, Secondary, and Higher Education

NASA's Earth Explorers Series supports educator enhancement and systemic improvement in elementary, secondary, higher, and informal education by encouraging the use of NASA-unique resources in Earth system and climate research.

Training Programs

Earth System Science Fellowship Program—This program supports individuals pursuing master's or Ph.D. degrees in Earth system science, climate change, and related research.

New Investigator Program in Earth Science—This program encourages integrated environments for research and education for scientists and engineers in Earth–Sun systems and climate research at the early stages of their professional careers.

On-line Resource or Information Centers

Earth System Science Learning Resources—NASA produces and sponsors a wide-ranging suite of Earth system science education products for elementary through postsecondary instruction and informal education.

Earth Observatory Newsroom—NASA's on-line newsroom for journalists features the latest news on Earth science research released from all NASA centers and more than 80 universities participating in NASA's Earth programs through sponsored research. NASA's Earth Observing System also provides journalists with a ready source of international expertise on global climate change science and policy.

Climate Change Outreach and Education

Press Releases—NASA's press releases on climate change science often result in feature articles in the media.

Visuals—NASA also produces visuals to help explain climate change science concepts to the media and prepares "Science Writers Guides" for NASA's climate change-related missions, which are distributed at press briefings and available on-line through the Earth Observatory Newsroom.

NASA Television—NASA Television programming is made available to television outlets and reformatted for formal and informal educational settings. It is also presented to tens of thousands of people in a live theater format at various education, science, and public events.

Science for the Public—In addition, NASA funds thousands of scientists at NASA centers and in academia who give public talks and interviews explaining the science of climate change.

Video Library—NASA Television maintains a library of video news releases and educational videos for distribution to the media, educational institutions, and the public. These videos include data visualizations, conceptual animations, and interviews with expert scientists on the subject of climate change.

NASA Publications—NASA also publishes brochures, fact sheets, and lithographs explaining climate change science. The Global Change Master Directory brochure and website point users to where they can obtain data on Earth science and climate change.

Competitive Solicitations—NASA funds universities, museums, professional societies, and NGOs to provide climate change-related education through competitive solicitations for education and outreach programs.

Partnerships

GLOBE Program—Through a consortium of scientists, institutional partners, and schools in 107 countries, the Global Learning and Observations to Benefit the Environment (GLOBE) Program, jointly sponsored by NASA, the National Science Foundation (NSF), and the Department of State, aims to improve student achievement in science and mathematics, increase scientific understanding of the Earth system and climate, and enhance the environmental awareness of individuals worldwide.

Television Productions—NASA often collaborates on its television productions with partners like USGS, the National Snow and Ice Data Center, the U.S. Forest Service, and EPA.

Research Support—NASA's Socioeconomic Data and Applications Center partnered with the SysTem for Analysis, Research and Training, USAID, the United Nations Environment Programme, the Third World Academy of Sciences, and the NASA Goddard Institute for Space Studies in supporting the Data, Methods, and Synthesis Activity of the Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors, including support for researchers in developing countries.

U.S. Department of Commerce/National Oceanic and Atmospheric Administration

Climate Education Working Group

This group develops education and outreach products, activities, and lesson plans for K-16 teachers and the general public to enhance their understanding of climate change and other important climate topics.

Climate and Global Change Postdoctoral Fellowship Program

This program is helping to create the next generation of climate researchers who will predict and assess global climate change on seasonal-to-centennial time scales. More than 100 program participants have worked at agencies, laboratories, and institutions of higher education.

National Climatic Data Center

The National Climatic Data Center maintains the world's largest archive of weather-related data used by specialists in meteorology, insurance, and agriculture,

and indirectly in most business sectors. The center includes a section on paleoclimate data, which was developed to help educate, inform, and highlight the importance of paleoclimate research in helping scientists and others better understand global warming, climate variability, and climate change.

Climate Prediction Center

The Climate Prediction Center develops climate outlook products to help farmers, businesses, and the public better plan for extreme weather events related to climate variations. It issues drought, hurricane, and winter outlooks, along with El Niño-Southern Oscillation advisories, and threats assessments.

National Science Foundation

Consistent with its mission to support research and education across a broad range of science and engineering disciplines, NSF funds research in numerous areas related to global climate change. NSF's Directorates for Geosciences; Biological Sciences; Social, Behavioral, and Economic Sciences; Education and Human Resources; Mathematics and Physical Sciences; Computer and Information Science and Engineering; and the Office of Polar Programs participate in the Climate Change Science Program and provide access to climate-related results from principal investigators.

NSF is the principal federal agency charged with promoting science and engineering (S&E) education. To this end, NSF supports the development of a diverse and well-prepared scientific and technical workforce, and a scientifically literate citizenry. NSF programs support:

- the development of instructional materials, curricula, and methods for kindergarten through graduate school;
- programs that increase public interest, understanding, engagement and lifelong learning in S&E, including informal education, such as museum exhibits and IMAX films;
- robust research and development of effective S&E education practices; and
- broadening participation of underrepresented groups, geographic regions, and types of institutions in all S&E fields.

Because NSF provides awards—principally to academic institutions—to accomplish these objectives, it does not directly disseminate climate information. The agency provides support to the principal investigators to develop results, databases, and educational practices that the scientific community uses for research and education purposes. In addition to funded education projects, investigators at academic institutions who conduct research related to climate change contribute to the education of undergraduate, graduate, and postdoctoral students who work on those research projects.

NSF partners with other agencies to support specific programs related to education, training, and outreach. Examples include the GLOBE Program and the SysTem for Analysis, Research and Training (START). (See Chapter 8 for more activities.)

NSF's Office of Legislative and Public Affairs works with the media, federal and state government representatives, industry representatives, and NSF grantees to facilitate a broader understanding of science and global climate change. Outreach activities include news releases, in-depth special reports, and special events open to the public.

OTHER FEDERAL ACTIVITIES

Climate Change Science Program

The Climate Change Science Program (CCSP) is responsible for communicating with a variety of stakeholders nationally and globally on issues related to climate variability and climate change science. The Communications Interagency Working Group leads CCSP's coordinated interagency communications efforts by:

- assisting in developing communications strategies and materials for synthesis and assessment products issued by CCSP working groups and affiliated agencies;
- developing and advancing a strategy for improving, integrating, and promoting the content of websites operated or supported by CCSP and its participating agencies, recognizing that the sites are essential communication and outreach tools; and
- identifying opportunities for outreach to specific audiences through constituent briefings, exhibits at science conferences, and placement of CCSP speakers on panels.

Highlights of Recent CCSP Interagency Communications Activity

Following are highlights of recent CCSP communications activities coordinated at the interagency level:

- Published and distributed *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2007 (CCSP and SGCR 2006a).*
- Published *Ecosystems and Climate Change: Research Priorities for the USCCSP* in 2006 (Lucier et al. 2006).
- Managed and improved CCSP websites, which receive an average of 5,000 hits a day.
- Assumed responsibility for the Global Change Research Information Office, which disseminates U.S. scientific research information that would be useful in preventing, mitigating, or adapting to the effects of global change.

Highlights of CCSP Interagency Communications Plans Through FY 2007

Some of the communications activities coordinated at the interagency level and planned through FY 2007 include the following:

- Prepare, publish, and disseminate the fiscal year 2007 and 2008 editions of *Our Changing Planet.*
- Disseminate new synthesis and assessment products, effectively communicating important conclusions to the relevant stakeholder communities.
- Facilitate stakeholder participation in the U.S. government review of draft documents from the Intergovernmental Panel on Climate Change.
- Maintain and enhance the content and services of the CCSP website.

Smithsonian Institution

Every year millions of U.S. and foreign visitors view Smithsonian exhibits in Washington, D.C., New York City, and other cities hosting Smithsonian traveling exhibits. In fulfilling its mission to promote the "increase and diffusion of knowledge," the Smithsonian educates the public about many areas of science, including global warming.

Deltas-Global Change Program

Initiated at the Smithsonian's National Museum of Natural History in 1995, this multidisciplinary, multinational research program assesses geological and environmental changes that seriously affect selected deltas in different climatic regions around the world.

Forces of Change

Through exhibits, publications, computer projects, and a variety of public programs, the National Museum of Natural History's *Forces of Change* examines the connections among the physical, biological, and cultural forces that shape the world. The program helps people see connections between seemingly remote forces, such as gas bubbles within the Antarctic ice cap and famines in tropical Africa. The museum's Global Links and Antarctica exhibits are examples of how *Forces of Change* communicates these connections.

Arctic Studies Center

The Arctic Studies Center invites the public to explore the history of northern populations, cultures, and environments and the issues that matter to northern residents today, including climate change. Visitors can excavate arctic sites, support indigenous efforts to preserve cultural heritage, and work with communities and scholars to share the treasures preserved in museum collections and archives.

TABLE 9-1 **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT		
Global Climate Change Program	Provides an overview of the program and its efforts in more than 40 countries.	http://www.usaid.gov/our_work/environment/climate/pub_outreach/index.html
Mexico Landfill Gas Partnership	Helps evaluate the feasibility and potential benefits of collecting and using landfill gas for energy recovery in Mexico.	http://www.epa.gov/lmop/international.htm
Global Partnerships	Describes the programs that support USAID's efforts to improve conditions for people around the world.	http://www.usaid.gov/our_work/global_partnerships/
U.S. DEPARTMENT OF AGRICULTURE		
Agricultural Research Service		
ARS Global Change Programs	Discusses the program's background, goals, and research components.	http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=204
Agriculture Research	Provides on-line access to USDA's monthly science magazine.	http://www.ars.usda.gov/is/AR/
Global Change Program Office	Coordinates climate change activities across USDA agencies, and interacts with other federal agencies, the legislative branch, and international partners on climate change issues affecting agriculture and forestry.	http://www.usda.gov/oce/global_change/index.htm
Natural Resources Conservation Service		
NRCS Fact Sheet	Presents opportunities for managing carbon sequestration and reducing GHGs using conservation incentive programs.	http://www.nrcs.usda.gov/feature/outlook/Carbon.pdf
Voluntary Reporting On-line Carbon Management Tool	Provides an on-line tool for estimating and voluntarily reporting carbon sequestration and GHG emissions.	http://cometvr.colostate.edu/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
U.S. DEPARTMENT OF ENERGY		
Carbon Dioxide Information Analysis Center	Responds to information requests from users concerned about the greenhouse effect and climate change.	http://cdiac.esd.ornl.gov/
Climate Change Technology Program	Provides a wealth of information and reports on technologies being developed to mitigate climate change.	www.climatetechnology.gov/
Climate VISION Program	Provides information on activities being pursued under this voluntary public–private partnership program to reduce greenhouse gas emissions.	http://www.climatevision.gov/
Enhancing DOE's 1605(b) Voluntary Greenhouse Gas Registry Program	Serves as a source of information on revisions to the "1605(b)" voluntary GHG registry.	http://www.pi.energy.gov/enhancing GHGregistry/index.html
Energy Information Administration	Provides all manner of current and historical energy data.	http://www.eia.doe.gov/
National Institute for Global Environmental Change	Helps decision makers and communities better respond to regional-scale or ecosystem-scale effects of climate change, and educates the public on climate change and energy-related environmental risks.	http://nigec.ucdavis.edu/
Energy Efficiency and Renewable Energy		
Office of Energy Efficiency and Renewable Energy	Describes DOE's work toward enhancing U.S. energy efficiency and expanding sources of renewable energy.	http://www.eere.energy.gov/
Building Technologies Program	Offers information on reducing energy consumption in homes and other buildings.	http://www.eere.energy.gov/buildings/
Building Toolbox	Presents a comprehensive guide and software tools for designing, constructing, or renovating more efficient, affordable buildings.	http://www.eere.energy.gov/buildings /info/toolboxdirectory.html
ENERGY STAR	Offers businesses and consumers energy-efficient solutions that save money and reduce GHG emissions (joint program with EPA).	http://www.energystar.gov/
FreedomCAR and Vehicle Technologies Program	Provides information on the program's goal of examining the research needed to improve vehicle fuel efficiency.	http://www1.eere.energy.gov/vehicles andfuels/about/partnerships/freedomcar /index.html
Energy Hog Campaign Site	Presents information about improving energy efficiency in the home.	http://www.energyhog.org/
Energy Savers	Provides homeowners with tips on saving energy and money.	http://www.eere.energy.gov/consumer/tips/
Home Energy Saver	Offers the first web-based do-it-yourself energy audit tool.	http://hes.lbl.gov/
Hydrogen Fuel		
Hydrogen Fuel Initiative	Provides information on this Presidential initiative to reduce America's dependence on foreign oil.	http://www.eere.energy.gov/hydrogen andfuelcells/presidents_initiative.html
International Partnership for the Hydrogen Economy	Describes the partnership's work to accelerate the development of hydrogen and fuel cell technologies.	http://www.iphe.net/
FutureGen Project	Presents an initiative to build the world's first integrated sequestration and hydrogen production research power plant.	http://www.fe.doe.gov/programs/ powersystems/futuregen/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
Fossil Energy and Carbon Sequestration		
Office of Fossil Energy	Describes DOE programs in fossil energy research and development.	http://fossil.energy.gov/
DOE Carbon Sequestration Programs	Examines DOE's research and development programs in carbon capture and storage.	http://fossil.energy.gov/programs/sequestration/
Carbon Sequestration Regional Partnerships	Discusses the public- and private-sector partnership efforts to determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration.	http://fossil.energy.gov/programs/sequestration/partnerships/index.html
Carbon Sequestration Leadership Forum (CSLF)	Reviews CSLF activities toward developing cost-effective technologies for capturing and storing CO_2.	http://www.cslforum.org/
Nuclear Energy		
Office of Nuclear Energy	Describes DOE programs in nuclear fission research and development.	http://www.ne.doe.gov/
Generation IV Nuclear Energy Systems Initiative	Discusses DOE's research into the next generation of nuclear systems.	http://nuclear.energy.gov/
Global Nuclear Energy Partnership	Provides information on the partnership, grants, and job opportunities.	http://www.gnep.energy.gov/default.html
Fusion Energy		
Fusion Energy Sciences	Describes DOE programs in the fusion energy sciences.	http://www.sc.doe.gov/feature/fes.htm
ITER Project	Describes the work of an international partnership toward demonstrating the feasibility of using fusion power to produce electricity.	http://www.iter.org/
Resources for Educators and Students		
For Students and Kids	Offers on-line energy, engineering, and science education for kids.	http://www.energy.gov/forstudentsandkids.htm
For Educators	Provides details on educational resources, scholarships and internships, contests and competitions, and support for schools and universities.	http://www.energy.gov/foreducators.htm
EERE Kids—Dr. E's Energy Lab	Provides an on-line resource for kids on all types of energy efficiency and renewable energy.	http://www.eere.energy.gov/kids/index.html
Ask a Scientist	Serves as an archive of answers to science questions from K-12 students and teachers, and an opportunity to ask new questions.	http://www.newton.dep.anl.gov/aas.htm
Resources for Researchers		
Research and Grant Programs	Provides information on support for research and development programs, educational institutions, and careers at DOE.	http://www.energy.gov/forresearchers.htm
Office of Science	Describes DOE's fundamental research programs.	http://www.sc.doe.gov/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
U.S. DEPARTMENT OF THE INTERIOR		
National Park Service		
Greening of the National Park Service	Promotes the use of sustainable energy and practice of environmental leadership in national parks.	http://www.nps.gov/renew/
Climate Friendly Parks Initiative	Provides an overview of this joint NPS/EPA energy efficiency initiative.	http://www.nps.gov/climatefriendlyparks/
Sustainability News	Published biannually, asks important questions about and offers appropriate responses to reducing GHG emissions and mitigating the effects of climate change.	http://www.nature.nps.gov/SustainabilityNews/index.htm
U.S. Geological Survey		
The USGS and Science Education	Provides public information about natural resources, natural hazards, geospatial data, and quality-of-life issues.	http://education.usgs.gov/
Earth Surface Dynamics Program	Presents USGS global change research activities, data sets, fact sheets, frequently asked questions, and information about the U.S. Climate Change Science Program.	http://geochange.er.usgs.gov/
U.S. DEPARTMENT OF TRANSPORTATION		
Center for Climate Change and Environmental Forecasting	Provides data on national and global transportation-related emissions, and information about related research projects, reports, partnerships, and events.	http://www.volpe.dot.gov/
It All Adds Up to Cleaner Air	Educates the public about the connections between their transportation choices, traffic congestion, and air pollution.	http://climate.volpe.dot.gov/addsup.html
U.S. ENVIRONMENTAL PROTECTION AGENCY		
Partnership Programs		
EPA's State and Local Clean Energy Programs	Provides information about EPA's support of the clean energy efforts of state and local governments.	http://epa.gov/cleanenergy/stateandlocal/
Business/Industry Outreach	Presents key sources for partnership programs for reducing GHG emissions.	http://www.epa.gov/air/ccd.html http://www.epa.gov/cppd/ http://www.epa.gov/otaq/
ENERGY STAR	Helps businesses and homes save money and protect the environment through energy-efficient products and practices (joint program with DOE).	http://energystar.gov/
Climate Leaders	Describes EPA's work with companies to develop long-term, comprehensive climate change strategies.	http://www.epa.gov/climateleaders/
SmartWay Transport Partnership	Establishes incentives between various freight industry sectors and EPA to improve fuel efficiency and reduce GHG emissions.	http://www.epa.gov/SmartwayLogistics/swplan.htm
Green Power Partnership	Discusses EPA's support of organizations that are buying or planning to buy electricity generated from renewable energy sources.	http://www.epa.gov/greenpower/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
Methane Reduction and Recovery Partnerships		
Methane to Markets Partnership	Describes an international initiative that promotes cost-effective methane recovery and use in agriculture, coal mines, landfills, and oil and gas systems.	http://www.epa.gov/methanetomarkets/
AgSTAR Program	Encourages the use of methane recovery (biogas) technologies at confined animal feeding operations that manage manure as liquids or slurries. (Sponsored with USDA and DOE.)	http://epa.gov/agstar/
Coalbed Methane Outreach Program	Discusses EPA's work with coal companies and related industries to reduce methane emissions.	http://epa.gov/cmop/
Landfill Methane Outreach Program	Promotes the use of landfill gas as a renewable, green energy source.	http://epa.gov/lmop/
Natural Gas STAR Program	Identifies and promotes the implementation of cost-effective technologies and practices to reduce methane emissions from the oil and natural gas industry.	http://epa.gov/gasstar/
Climate Change Outreach and Education		
Climate Change	Educates general audiences about climate change science and impacts, GHG emissions, and mitigation actions.	http://www.epa.gov/climatechange/
Climate Change, Wildlife, and Wildlands Toolkit for Teachers and Interpretors	Contains materials for educating the public about how climate change is affecting U.S. wildlife and public lands. Produced in partnership with NPS and the U.S. Fish and Wildlife Service.	http://epa.gov/climatechange/wycd/ORWKit.html
Sea Level Rise Reports	Provides an extended abstract on which EPA sea level rise reports produced over the past 25 years contain relevant information on particular issues and what to read first.	http://epa.gov/climatechange/effects/coastal/slrreports.html
Harvard Green Campus Initiative	Presents an on-line manual designed to help colleges and universities initiate student internship programs aimed at improving energy efficiency and reducing GHG emissions.	http://www.greencampus.harvard.edu/greenteams
Climate Change Kids Site	Explains global warming and climate science and includes interactive games about climate change.	http://epa.gov/climatechange/kids/index.html
Global Warming Wheel Card Classroom Activity Kit	Helps students link their own energy use to global warming.	http://epa.gov/climatechange/downloads/ActivityKit.pdf
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION		
Climate Change Outreach and Education		
NASA Education Links and Publications	Offers brochures, fact sheets, and lithographs explaining climate change science.	http://disc.gsfc.nasa.gov/education_links.shtml http://eospso.gsfc.nasa.gov/eos_homepage/for_educators/educational_publications.php
Students' Cloud Observations On-line Project	Provides information on climate change in the context of the effects of clouds on climate.	http://asd-www.larc.nasa.gov/SCOOL/
The GLOBE Program	Offers participants in the GLOBE Program, grades K-12, an interactive science and education learning experience.	http://www.globe.gov/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
Climate Change Outreach and Education (continued)		
Earth Science Frequently Asked Questions	Provides answers to frequently asked questions about global environmental change.	http://gcmd.nasa.gov/Resources/FAQs/faqpage.html
State of the Cryosphere	Provides educational material on the status of snow and ice as indicators of climate change.	http://nsidc.org/sotc/
Earth Explorers Series	Encourages educators to use NASA-unique resources in Earth system and climate research.	http://science.hq.nasa.gov/education/earth_explorers/index.html
Earth System Science Fellowship Program	Supports individuals pursuing master's or Ph.D. degrees in Earth system science, climate change, and related research.	http://research.hq.nasa.gov/code_y/nra/current/Fellowship-ESS01/
Earth Science Education Plan	Characterizes the overriding principles, objectives, and plan for ensuring the successful results of Earth science communication efforts.	http://science.hq.nasa.gov/research/epo.htm
Resource and Information Centers		
Earth System Science Learning Resources	Lists on-line resources for a wide-ranging suite of Earth system science education products.	http://science.hq.nasa.gov/education/catalog/resources/resources_index.html
Global Change Master Directory Learning Center	Contains data and information about global environmental change.	http://gcmd.nasa.gov/Resources/Learning/
Goddard Institute for Space Studies	Offers information about the scientific results of climate modeling, as well as educational opportunities.	http://www.giss.nasa.gov/
Earth Observatory	Publishes satellite imagery and scientific information focusing on the Earth's climate and environmental change.	http://www.earthobservatory.nasa.gov/
Earth Observatory Newsroom	Features the latest news on Earth science research released from all NASA centers and more than 80 universities participating in NASA's Earth programs.	http://www.earthobservatory.nasa.gov/Newsroom
New Investigator Program in Earth Science	Encourages climate research at the early stages of the professional careers of scientists and engineers.	http://www.nasa.gov/audience/foreducators/postsecondary/features/F_New_Investigator_Program.html
Climate Change Products		
Scientific Visualization Studio	Presents numerous data visualizations relating to changes in the Earth's climate, including the Conceptual Imaging Lab's animations of Earth's complex processes.	http://svs.gsfc.nasa.gov/
Global Change Master Directory	Points users to information about climate change data and services.	http://gcmd.nasa.gov/
Daily Earth Temperatures from Satellites	Contains information on global atmospheric temperature trends.	http://pm-esip.nsstc.nasa.gov/amsutemps/
Goddard TV	Presents video news releases and educational videos that include data visualizations, conceptual animations, and interviews with expert scientists on the subject of climate change.	http://www.gsfc.nasa.gov/gtv.html
Assessments of Impacts and Adaptations to Climate Change	Facilitates access to extensive data, software, and bibliographic resources related to climate impacts, adaptation, and vulnerability across multiple sectors.	http://sedac.ciesin.columbia.edu/aiacc/

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
U.S. DEPARTMENT OF COMMERCE/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		
Resources for Educators and Students		
NOAA's Education Resources	Helps students, teachers, librarians and the general public access the NOAA's educational activities, publications, and booklets.	http://www.education.noaa.gov/
Climate Change and Our Planet: Specially for Kids	Lists NOAA's sites related to climate change tailored for kids in grades K-5.	http://www.education.noaa.gov/sclimate.html
Climate Change and Our Planet: Specially for Teachers	Lists NOAA's sites related to climate change tailored for educators.	http://www.education.noaa.gov/tclimate.html
OGP Video Library	Offers links to numerous videos on climate change.	http://www.ogp.noaa.gov/streams/index.html
Resources for Researchers		
A Paleo Perspective on Global Warming	Explains the importance of paleoclimate research and its relation to global warming.	http://www.ngdc.noaa.gov/paleo/globalwarming/home.html
Climate Program Office	Contains a variety of climate change topics, articles, and funding opportunities.	http://www.climate.noaa.gov/
Climate and Global Change Postdoctoral Fellowship Program	Provides information and application instructions for postdoctoral researchers seeking to be paired with host scientists at U.S. institutions working on climate studies.	http://www.vsp.ucar.edu/cgc.html
Climate-Related Products and Services		
Climate Portal	Provides access to a variety of NOAA's climate-related products, services, and organizations.	http://www.noaa.gov/climate.html
National Climatic Data Center	Provides access to an extensive database of weather-related information.	http://www.ncdc.noaa.gov/
Climate Prediction Center Educational Materials	Offers educational materials to help farmers, businesses, and the public understand the role of the climate system and to better plan for extreme weather events related to climate variations.	http://www.cpc.ncep.noaa.gov/products/outreach/education.shtml http://www.cpc.ncep.noaa.gov/products/expert_assessment
NATIONAL SCIENCE FOUNDATION		
NSF Special Reports		
Arctic Climate Change	Explores the complex factors that influence climate change, which require a multifaceted approach—from ships at sea to snowmobiles in Alaska—to study the process.	http://www.nsf.gov/news/special_reports/arctic/index.jsp
Ecology of Infectious Diseases	Discusses efforts to understand the underlying ecological and biological mechanisms behind human-induced environmental changes and the emergence and transmission of infectious diseases.	http://www.nsf.gov/news/special_reports/ecoinf/index.jsp
Autumn Weather Predicts Winter Snows	Explores the major role of large-scale weather patterns in controlling seasonal weather, along with the conditions of these atmospheric oscillations, to significantly improve long-range weather predictions.	http://www.nsf.gov/news/special_reports/autumnwinter/index.jsp
The (Environmental) Sensor Revolution	Introduces the Sensor Revolution—the world's first electronic nervous system.	http://www.nsf.gov/news/special_reports/sensor/index.jsp
Seafloor Science	Uncovers the mysteries of the ocean's most extreme environment—the seafloor.	http://www.nsf.gov/news/special_reports/sfs/index.jsp

TABLE 9-1 (Continued) **Governmental On-line Climate Change Educational Resources**

Resource	Description	Website
CLIMATE CHANGE SCIENCE PROGRAM		
CCSP	Provides information about the program and CCSP products and resources.	http://www.climatescience.gov/
U.S. Global Change Research Information Office (GCRIO)	As mandated in the Global Change Research Act, GCRIO is responsible for the physical and electronic dissemination of information resulting from the U.S. climate program.	http://www.gcrio.org/
SMITHSONIAN INSTITUTION		
Climate-Related Outreach and Education		
Global Warming: Focus on the Future	This web version of an exhibit that toured the U.S. encourages visitors to learn about the history of global warming, examines why it is a problem, and empowers them to help solve the problem.	http://globalwarming.enviroweb.org/
Forces of Change	Examines the connections among the physical, biological, and cultural forces that shape the world.	http://forces.si.edu/
Arctic Studies Center	Explores the history of northern peoples, cultures, and environments and such critical issues as climate change.	http://www.mnh2.si.edu/arctic/
Resources for Researchers		
Deltas-Global Change Program	Describes the research that drives this multidisciplinary, multinational program.	http://www.nmnh.si.edu/paleo/deltas/
Migratory Bird Center	Explores how climate change affects birds' migratory patterns.	http://nationalzoo.si.edu/ConservationAndScience/MigratoryBirds/research/climate_change/default.cfm#ContentArea

Appendix A
Emission Trends

TABLE 10 EMISSIONS TRENDS (CO_2)
(Sheet 1 of 5)
(Part 1 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg									
1. Energy	**4,830,463.65**	**4,797,772.12**	**4,894,421.31**	**5,026,716.65**	**5,103,983.53**	**5,154,192.67**	**5,341,931.95**	**5,407,934.05**	**5,448,279.22**	**5,527,589.28**
A. Fuel Combustion (Sectoral Approach)	4,824,658.59	4,791,898.96	4,889,114.46	5,019,920.64	5,097,120.91	5,145,205.92	5,333,482.87	5,400,050.40	5,441,713.05	5,520,846.48
1. Energy Industries	1,795,514.03	1,791,841.24	1,804,521.58	1,884,778.53	1,911,285.04	1,926,381.19	1,997,372.76	2,066,327.31	2,154,894.35	2,165,584.61
2. Manufacturing Industries and Construction	851,114.88	820,172.80	874,057.19	865,307.09	871,174.02	876,389.22	918,750.19	912,431.43	871,919.08	849,811.39
3. Transport	1,413,240.29	1,385,651.43	1,431,515.50	1,481,263.62	1,519,392.86	1,548,355.01	1,584,231.84	1,601,594.88	1,629,624.36	1,693,297.10
4. Other Sectors	560,574.62	571,043.83	576,871.67	585,861.58	578,965.87	579,563.37	620,733.97	599,063.30	551,234.11	570,920.52
5. Other	204,214.77	213,189.67	201,548.51	204,718.82	215,903.12	214,537.13	212,313.92	220,633.48	234,041.15	241,833.06
B. Fugitive Emissions from Fuels	5,805.06	5,873.16	5,306.85	6,786.82	6,862.62	8,986.76	8,529.28	7,873.65	6,566.19	6,942.79
1. Solid Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Oil and Natural Gas	5,805.06	5,873.16	5,306.85	6,786.82	6,862.62	8,986.76	8,529.28	7,873.65	6,566.19	6,942.79
2. Industrial Processes	**174,791.23**	**164,064.88**	**163,275.30**	**160,590.15**	**167,670.45**	**171,896.92**	**166,796.32**	**172,944.33**	**171,896.90**	**167,450.15**
A. Mineral Products	54,195.19	52,614.59	53,181.47	55,228.29	57,676.50	61,320.82	62,635.64	63,611.55	64,911.37	65,757.41
B. Chemical Industry	25,523.61	25,110.36	26,329.81	26,747.48	27,919.36	27,317.42	27,166.51	27,926.24	29,462.50	28,047.48
C. Metal Production	95,272.43	86,339.93	83,764.02	78,614.38	82,074.59	82,459.48	76,994.17	81,406.55	77,523.03	73,665.25
D. Other Production	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
E. Production of Halocarbons and SF_6										
F. Consumption of Halocarbons and SF_6										
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
3. Solvent and Other Product Use	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**
4. Agriculture										
A. Enteric Fermentation										
B. Manure Management										
C. Rice Cultivation										
D. Agricultural Soils										
E. Prescribed Burning of Savannas										
F. Field Burning of Agricultural Residues										
G. Other										
5. Land Use, Land-Use Change and Forestry[2]	**-910,373.10**	**-908,515.44**	**-872,606.25**	**-751,969.44**	**-747,840.43**	**-614,886.87**	**-603,849.95**	**-641,272.35**	**-744,041.71**	**-765,692.34**
A. Forest Land	-563,339.86	-574,330.65	-530,219.65	-409,757.66	-397,597.11	-285,402.91	-272,053.43	-300,736.28	-412,697.88	-423,203.94
B. Cropland	-31,632.43	-31,680.75	-32,216.90	-34,027.79	-33,772.41	-29,199.57	-29,119.57	-29,538.60	-27,385.35	-27,409.07
C. Grassland	-22,154.74	-22,251.06	-22,311.10	-22,417.88	-22,492.53	-13,548.90	-13,573.07	-13,587.94	-13,602.81	-13,643.71
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Settlements	-83,187.81	-82,294.14	-85,107.59	-82,084.07	-83,138.29	-83,518.30	-81,518.27	-84,838.19	-84,232.80	-86,773.77
F. Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
G. Other	-210,058.25	-197,978.84	-202,751.02	-203,682.04	-210,440.09	-203,216.99	-207,585.69	-212,731.34	-206,122.86	-214,661.85
6. Waste	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**
A. Solid Waste Disposal on Land	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B. Waste-water Handling										
C. Waste Incineration	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
D. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Other non-specified	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total CO_2 emissions including net CO_2 from LULUCF[3]	**4,094,881.78**	**4,053,321.56**	**4,185,090.35**	**4,435,337.16**	**4,523,813.55**	**4,710,482.73**	**4,904,878.32**	**4,939,596.13**	**4,876,134.41**	**4,929,347.08**
Total CO_2 emissions excluding net CO_2 from LULUCF[3]	**5,005,254.88**	**4,961,837.00**	**5,057,696.60**	**5,187,306.61**	**5,271,653.98**	**5,325,369.59**	**5,508,728.27**	**5,580,868.48**	**5,620,176.12**	**5,695,039.42**
Memo Items:										
International Bunkers	**113,582.67**	**119,859.04**	**109,722.60**	**99,751.86**	**97,724.81**	**100,678.57**	**102,294.91**	**109,858.16**	**114,557.44**	**105,228.61**
Aviation	46,230.19	46,521.67	46,900.62	47,481.50	48,035.25	50,749.98	52,186.06	55,898.55	56,657.37	58,799.49
Marine	67,272.48	73,337.37	62,821.98	52,270.36	49,689.56	49,928.59	50,108.85	53,959.61	57,900.06	46,428.92
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**216,702.82**	**217,567.47**	**228,141.27**	**222,383.36**	**231,283.15**	**243,502.30**	**244,305.64**	**233,243.16**	**217,201.03**	**222,360.14**

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (CO_2)
(Sheet 1 of 5)
(Part 2 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg					%
1. Energy	**5,658,886.35**	**5,642,663.67**	**5,663,383.81**	**5,750,038.56**	**5,835,334.67**	**20.80**
A. Fuel Combustion (Sectoral Approach)	5,692,317.61	5,636,569.62	5,657,080.21	5,723,937.59	5,829,300.81	20.82
1. Energy Industries	2,269,311.57	2,237,292.82	2,233,455.50	2,262,197.79	2,290,619.61	27.57
2. Manufacturing Industries and Construction	862,564.74	861,167.85	842,119.24	844,620.59	863,461.40	1.45
3. Transport	1,738,562.74	1,725,588.49	1,771,756.85	1,772,254.33	1,825,651.34	29.18
4. Other Sectors	595,143.90	586,388.01	584,324.43	614,563.10	595,585.26	6.25
5. Other	232,334.67	226,212.45	225,424.19	230,301.78	254,003.20	24.38
B. Fugitive Emissions from Fuels	5,768.54	6,094.04	6,203.59	6,090.97	6,033.86	3.94
1. Solid Fuels	NE	NE	NE	NE	NE	0.00
2. Oil and Natural Gas	5,768.54	6,094.04	6,203.59	6,090.97	6,033.86	3.94
2. Industrial Processes	**166,378.73**	**152,528.56**	**152,605.17**	**147,648.81**	**152,649.74**	**-12.67**
A. Mineral Products	64,852.48	64,065.15	65,230.52	64,901.51	70,163.13	29.46
B. Chemical Industry	27,007.54	23,539.05	25,774.86	22,853.69	24,758.35	-2.23
C. Metal Production	74,518.71	64,924.36	61,599.79	59,893.61	57,728.26	-39.41
D. Other Production	NE	NE	NE	NE	NE	0.00
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6						
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.00
3. Solvent and Other Product Use	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**0.00**
4. Agriculture						
A. Enteric Fermentation						
B. Manure Management						
C. Rice Cultivation						
D. Agricultural Soils						
E. Prescribed Burning of Savannas						
F. Field Burning of Agricultural Residues						
G. Other						
5. Land-Use, Land-Use Change and Forestry[1]	**-759,506.65**	**-767,987.44**	**-768,638.59**	**-774,847.66**	**-780,094.17**	**-14.31**
A. Forest Land	-420,195.58	-420,195.58	-420,195.58	-420,195.58	-420,195.58	-25.41
B. Cropland	-28,944.42	-30,595.97	-30,328.23	-31,503.42	-31,759.51	0.40
C. Grassland	-13,685.35	-13,726.78	-13,769.66	-13,814.02	-13,859.92	-37.44
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
E. Settlements	-85,865.99	-89,677.60	-89,936.27	-93,758.29	-97,311.28	16.98
F. Other Land	NE	NE	NE	NE	NE	0.00
G. Other	-210,815.31	-213,793.50	-214,408.85	-215,578.36	-216,967.88	5.29
6. Waste	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**0.00**
A. Solid Waste Disposal on Land	NA	NA	NA	NA	NA	0.00
B. Waste-water Handling						
C. Waste Incineration	IE	IE	IE	IE	IE	0.00
D. Other	NA	NA	NA	NA	NA	0.00
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**0.00**
Other non-specified	NA	NA	NA	NA	NA	0.00
Total CO_2 emissions including net CO_2 from LULUCF[2]	**5,104,958.25**	**5,027,204.79**	**5,047,259.39**	**5,102,839.71**	**5,107,890.25**	**27.18**
Total CO_2 emissions excluding net CO_2 from LULUCF[2]	**5,864,464.88**	**5,795,191.21**	**5,815,888.98**	**5,877,677.37**	**5,887,984.41**	**19.65**
Memo Items:						
International Bunkers	**101,366.67**	**97,814.95**	**89,488.77**	**84,683.30**	**94,498.89**	**-16.74**
Aviation	60,507.03	59,337.45	61,787.41	59,448.46	59,911.60	29.59
Marine	40,859.44	38,477.49	27,701.36	24,634.85	34,587.29	-48.59
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**0.00**
CO_2 Emissions from Biomass	**226,764.85**	**200,478.81**	**194,351.10**	**202,110.66**	**211,229.93**	**-2.53**

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (CH_4)
(Sheet 2 of 5)
(Part 1 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg									
Total CH_4 emissions	**29,431.60**	**29,436.93**	**29,668.61**	**28,899.39**	**29,161.28**	**28,997.40**	**28,533.54**	**28,039.31**	**27,594.86**	**27,093.90**
1. Energy	**12,458.65**	**12,366.48**	**12,225.90**	**11,660.87**	**11,716.55**	**11,696.29**	**11,687.13**	**11,613.55**	**11,210.59**	**10,800.17**
A. Fuel Combustion (Sectoral Approach)	598.51	599.51	613.80	588.13	581.13	590.66	593.59	588.13	506.50	508.29
1. Energy Industries	26.95	26.67	26.77	28.09	28.49	27.29	28.38	29.36	31.28	31.34
2. Manufacturing Industries and Construction	108.98	107.62	111.46	114.20	115.70	119.27	122.34	125.45	117.61	115.74
3. Transport	213.91	207.77	207.94	204.93	201.21	195.01	188.87	178.42	169.84	161.91
4. Other Sectors	244.74	253.59	263.90	237.19	231.96	247.59	252.67	203.47	184.31	195.84
5. Other	3.71	3.86	3.74	3.72	3.77	3.48	3.33	3.43	3.46	3.46
B. Fugitive Emissions from Fuels	11,860.34	11,766.96	11,612.10	11,072.74	11,135.42	11,105.65	11,093.54	10,875.42	10,704.09	10,291.87
1. Solid Fuels	4,186.17	4,056.25	3,984.15	3,429.25	3,487.42	3,522.95	3,407.47	3,341.12	3,317.66	3,136.97
2. Oil and Natural Gas	7,674.17	7,710.72	7,627.95	7,643.49	7,648.00	7,580.70	7,686.06	7,534.30	7,386.43	7,154.90
2. Industrial Processes	**119.57**	**114.42**	**120.20**	**126.99**	**132.65**	**135.95**	**137.40**	**138.64**	**137.50**	**137.78**
A. Mineral Products	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
B. Chemical Industry	56.77	58.91	61.63	67.29	72.36	73.68	76.98	79.09	80.69	82.02
C. Metal Production	62.80	55.51	58.57	59.70	60.29	62.27	60.42	59.55	57.21	55.77
D. Other Production										
E. Production of Halocarbons and SF_6										
F. Consumption of Halocarbons and SF_6										
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
3. Solvent and Other Product Use										
4. Agriculture	**7,468.13**	**7,519.49**	**7,621.28**	**7,585.55**	**7,833.34**	**7,969.44**	**7,759.78**	**7,759.86**	**7,828.99**	**7,810.10**
A. Enteric Fermentation	5,612.36	5,578.70	5,685.69	5,658.36	5,734.01	5,856.34	5,740.31	5,635.55	5,558.80	5,562.85
B. Manure Management	1,483.72	1,578.88	1,524.66	1,563.53	1,669.47	1,718.70	1,651.88	1,731.57	1,848.35	1,815.97
C. Rice Cultivation	339.21	333.19	374.79	334.24	391.13	392.90	331.73	356.24	376.26	369.87
D. Agricultural Soils	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
F. Field Burning of Agricultural Residues	32.83	30.73	36.14	29.02	38.73	31.50	35.84	36.51	37.58	36.51
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5. Land Use, Land-Use Change and Forestry	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**
A. Forest Land	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
B. Cropland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
C. Grassland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Settlements	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
F. Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
G. Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	**9,385.24**	**9,436.55**	**9,501.22**	**9,525.99**	**9,478.74**	**9,195.71**	**9,019.63**	**8,727.25**	**8,424.58**	**8,345.75**
A. Solid Waste Disposal on Land	8,205.61	8,209.12	8,219.31	8,208.67	8,104.02	7,772.54	7,557.44	7,217.94	6,874.39	6,743.43
B. Waste-water Handling	1,179.63	1,227.43	1,281.92	1,317.32	1,374.72	1,423.18	1,462.19	1,509.31	1,550.19	1,602.33
C. Waste Incineration	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
D. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Memo Items:										
International Bunkers	**7.88**	**8.39**	**7.38**	**6.38**	**6.15**	**6.25**	**6.30**	**6.78**	**7.19**	**6.13**
Aviation	1.27	1.28	1.29	1.31	1.32	1.40	1.44	1.54	1.58	1.62
Marine	6.53	7.11	6.10	5.08	4.82	4.85	4.86	5.24	5.63	4.51
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass										

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (CH_4)
(Sheet 2 of 5)
(Part 2 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg					%
Total CH_4 emissions	**26,997.19**	**26,679.00**	**26,657.36**	**26,874.81**	**26,511.31**	**-9.82**
1. Energy	**10,893.53**	**10,714.78**	**10,480.17**	**10,517.44**	**10,377.30**	**-17.51**
A. Fuel Combustion (Sectoral Approach)	512.75	474.40	447.10	455.08	446.59	-25.36
1. Energy Industries	32.40	32.16	31.98	33.10	33.43	24.02
2. Manufacturing Industries and Construction	117.32	110.11	108.15	106.70	110.82	1.68
3. Transport	155.85	146.65	139.43	131.02	126.19	-41.01
4. Other Sectors	203.77	181.30	163.74	180.11	171.74	-29.83
5. Other	3.42	4.18	3.80	4.15	4.41	18.85
B. Fugitive Emissions from Fuels	10,379.78	10,240.37	10,033.07	10,062.36	9,930.61	-17.11
1. Solid Fuels	3,822.39	2,956.39	2,787.76	2,888.02	2,951.20	-29.50
2. Oil and Natural Gas	7,357.39	7,283.99	7,245.32	7,174.34	6,879.41	-10.36
2. Industrial Processes	**137.82**	**119.45**	**128.43**	**121.34**	**127.17**	**6.35**
A. Mineral Products	IE	IE	IE	IE	IE	0.00
B. Chemical Industry	80.33	68.67	72.67	72.62	77.41	36.35
C. Metal Production	57.49	50.78	47.76	48.72	49.76	-20.77
D. Other Production						
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6						
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.00
3. Solvent and Other Product Use						
4. Agriculture	**7,713.89**	**7,709.98**	**7,692.83**	**7,711.89**	**7,639.94**	**2.30**
A. Enteric Fermentation	5,507.09	5,459.14	5,462.73	5,481.04	5,362.36	-4.45
B. Manure Management	1,811.35	1,850.37	1,871.30	1,864.62	1,875.45	26.40
C. Rice Cultivation	356.84	365.78	325.20	328.31	360.37	6.24
D. Agricultural Soils	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	0.00
F. Field Burning of Agricultural Residues	37.61	36.65	33.61	37.92	41.76	27.30
G. Other	NA	NA	NA	NA	NA	0.00
5. Land Use, Land-Use Change and Forestry	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**NA,NE**	**0.00**
A. Forest Land	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
B. Cropland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
C. Grassland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
E. Settlements	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
F. Other Land	NE	NE	NE	NE	NE	0.00
G. Other	NE	NE	NE	NE	NE	0.00
6. Waste	**8,253.95**	**8,134.82**	**8,363.93**	**8,524.14**	**8,467.80**	**-9.78**
A. Solid Waste Disposal on Land	6,618.57	6,484.23	6,658.73	6,782.47	6,708.96	-18.24
B. Waste-water Handling	1,635.37	1,650.59	1,705.19	1,741.67	1,758.84	49.03
C. Waste Incineration	NE	NE	NE	NE	NE	0.00
D. Other	NA	NA	NA	NA	NA	0.00
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**0.00**
	NA	NA	NA	NA	NA	0.00
Memo Items:						
International Bunkers	**5.65**	**5.37**	**4.40**	**4.04**	**5.02**	**-35.64**
Aviation	1.67	1.64	1.70	1.64	1.65	30.06
Marine	3.98	3.73	2.69	2.41	3.37	-48.42
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**0.00**
CO_2 Emissions from Biomass						

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (N_2O)
(Sheet 3 of 5)
(Part 1 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg									
Total N_2O emissions	**1,373.81**	**1,331.36**	**1,243.40**	**1,453.64**	**1,383.67**	**1,465.37**	**1,493.19**	**1,356.43**	**1,421.37**	**1,352.81**
1. Energy	**180.34**	**187.50**	**198.05**	**205.83**	**211.42**	**215.19**	**219.59**	**221.73**	**221.19**	**218.94**
A. Fuel Combustion (Sectoral Approach)	180.34	187.50	198.05	205.83	211.42	215.19	219.59	221.73	221.19	218.94
1. Energy Industries	24.40	24.33	24.59	25.70	25.84	25.87	27.26	28.01	28.72	28.79
2. Manufacturing Industries and Construction	12.87	12.54	13.01	13.47	13.48	13.66	14.08	14.22	13.47	13.43
3. Transport	136.21	142.94	152.68	159.38	164.91	168.35	170.80	172.89	172.86	170.45
4. Other Sectors	4.65	4.77	4.88	4.48	4.40	4.59	4.76	4.04	3.67	3.89
5. Other	3.20	2.93	2.91	2.80	2.78	2.72	2.68	2.57	2.47	2.38
B. Fugitive Emissions from Fuels	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE
1. Solid Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Oil and Natural Gas	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE
2. Industrial Processes	**106.59**	**105.41**	**101.14**	**105.80**	**111.73**	**119.66**	**121.77**	**101.71**	**86.68**	**82.58**
A. Mineral Products	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
B. Chemical Industry	106.59	105.41	101.14	105.80	111.73	119.66	121.77	101.71	86.68	82.58
C. Metal Production	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
D. Other Production										
E. Production of Halocarbons and SF_6										
F. Consumption of Halocarbons and SF_6										
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
3. Solvent and Other Product Use	**13.87**	**13.49**	**12.72**	**14.45**	**14.45**	**14.45**	**14.45**	**15.37**	**15.37**	**15.37**
4. Agriculture	**912.06**	**953.55**	**869.16**	**1,064.61**	**899.86**	**1,050.44**	**1,070.43**	**940.58**	**1,028.98**	**964.74**
A. Enteric Fermentation										
B. Manure Management	52.44	54.08	53.37	54.75	54.74	55.27	54.86	55.95	56.12	56.22
C. Rice Cultivation										
D. Agricultural Soils	858.41	898.30	814.46	1,008.76	843.65	993.95	1,014.11	882.18	971.38	907.09
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
F. Field Burning of Agricultural Residues	1.20	1.17	1.33	1.10	1.47	1.22	1.37	1.44	1.48	1.44
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5. Land Use, Land-Use Change and Forestry	**18.31**	**18.59**	**18.82**	**19.50**	**20.32**	**19.83**	**20.64**	**20.86**	**21.88**	**21.51**
A. Forest Land	0.19	0.19	0.30	0.36	0.42	0.60	0.77	0.96	1.14	1.50
B. Cropland	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE
C. Grassland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Settlements	18.12	18.40	18.52	19.14	19.90	19.23	19.87	19.89	19.93	20.00
F. Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
G. Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	**41.64**	**42.81**	**43.51**	**44.24**	**45.89**	**45.70**	**46.32**	**47.17**	**48.07**	**49.66**
A. Solid Waste Disposal on Land										
B. Waste-water Handling	41.64	42.81	43.51	44.24	45.89	45.70	46.32	47.17	48.07	49.66
C. Waste Incineration	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
D. Other	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Memo Items:										
International Bunkers	**3.13**	**3.27**	**3.03**	**2.79**	**2.75**	**2.84**	**2.89**	**3.10**	**3.21**	**3.01**
Aviation	1.46	1.47	1.48	1.50	1.52	1.61	1.65	1.77	1.80	1.86
Marine	1.66	1.81	1.55	1.29	1.22	1.23	1.23	1.33	1.43	1.14
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass										

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (N_2O)
(Sheet 3 of 5)
(Part 2 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg					%
Total N_2O emissions	**1,342.61**	**1,331.68**	**1,314.18**	**1,245.41**	**1,247.46**	**-2.87**
1. Energy	**207.61**	**206.22**	**197.68**	**189.91**	**183.59**	**1.46**
A. Fuel Combustion (Sectoral Approach)	207.61	206.22	197.68	189.91	183.59	1.46
1. Energy Industries	30.12	29.42	29.36	30.08	30.24	23.91
2. Manufacturing Industries and Construction	13.63	13.39	13.03	13.12	13.63	5.93
3. Transport	167.35	166.89	148.57	139.97	133.42	-2.05
4. Other Sectors	4.06	3.78	3.46	3.78	3.69	-20.82
5. Other	2.44	2.74	2.86	2.97	3.02	-5.75
B. Fugitive Emissions from Fuels	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	0.00
1. Solid Fuels	NE	NE	NE	NE	NE	0.00
2. Oil and Natural Gas	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	0.00
2. Industrial Processes	**82.67**	**67.20**	**74.54**	**73.85**	**72.13**	**-32.33**
A. Mineral Products	IE	IE	IE	IE	IE	0.00
B. Chemical Industry	82.67	67.20	74.54	73.85	72.13	-32.33
C. Metal Production	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	0.00
D. Other Production						
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6						
G. Other	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.00
3. Solvent and Other Product Use	**15.37**	**15.37**	**15.37**	**15.37**	**15.37**	**10.83**
4. Agriculture	**956.35**	**972.50**	**955.55**	**894.00**	**902.21**	**-1.08**
A. Enteric Fermentation						
B. Manure Management	57.58	58.28	58.02	56.56	57.05	8.78
C. Rice Cultivation						
D. Agricultural Soils	897.29	912.72	896.14	836.01	843.50	-1.74
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	0.00
F. Field Burning of Agricultural Residues	1.48	1.49	1.39	1.43	1.66	38.51
G. Other	NA	NA	NA	NA	NA	0.00
5. Land Use, Land-Use Change and Forestry	**20.56**	**20.13**	**20.61**	**21.22**	**22.06**	**20.47**
A. Forest Land	1.14	1.26	1.26	1.26	1.26	556.25
B. Cropland	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	0.00
C. Grassland	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
D. Wetlands	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	0.00
E. Settlements	19.42	18.85	19.35	19.95	20.80	14.78
F. Other Land	NE	NE	NE	NE	NE	0.00
G. Other	NE	NE	NE	NE	NE	0.00
6. Waste	**50.05**	**50.27**	**50.43**	**51.06**	**51.69**	**24.15**
A. Solid Waste Disposal on Land						
B. Waste-water Handling	50.05	50.27	50.43	51.06	51.69	24.15
C. Waste Incineration	IE	IE	IE	IE	IE	0.00
D. Other	IE	IE	IE	IE	IE	0.00
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**0.00**
	NA	NA	NA	NA	NA	0.00
Memo Items:						
International Bunkers	**2.92**	**2.83**	**2.66**	**2.50**	**2.75**	**-11.67**
Aviation	1.92	1.88	1.96	1.88	1.90	30.06
Marine	1.01	0.95	0.68	0.61	0.86	-48.42
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**0.00**
CO_2 Emissions from Biomass						

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (HFCs, PFCs and SF_6)
(Sheet 4 of 5)
(Part 1 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg									
Emissions of HFCs[20] - ($Gg CO_2$ equivalent)	**35,551.51**	**31,693.24**	**37,110.47**	**36,712.68**	**41,404.53**	**51,441.45**	**66,072.83**	**76,491.05**	**95,856.44**	**93,632.22**
HFC-23	3.01	2.65	3.00	2.74	2.72	2.34	2.65	2.60	3.47	2.64
HFC-32	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	0.14	0.29	0.43	0.44
HFC-41	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
HFC-43-10mee	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
HFC-125	IE,NA,NO	IE,NA,NO	0.21	0.45	0.79	1.30	1.87	2.52	3.13	3.57
HFC-134	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
HFC-134a	IE,NA,NO	IE,NA,NO	0.49	1.75	4.62	13.63	18.48	23.56	27.06	30.90
HFC-152a	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
HFC-143	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
HFC-143a	IE,NA,NO	IE,NA,NO	IE,NA,NO	0.03	0.09	0.20	0.53	0.93	1.37	1.74
HFC-227ea	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
HFC-236fa	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	0.01	0.06	0.14
HFC-245ca	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO	C,IE,NA,NO
Unspecified mix of listed HFCs[20] - ($Gg CO_2$ equivalent)	392.46	742.33	822.62	903.28	976.38	1,972.29	3,219.83	3,943.05	4,614.62	4,767.06
Emissions of PFCs[20] - ($Gg CO_2$ equivalent)	**20,644.70**	**17,818.50**	**16,586.86**	**16,534.65**	**15,171.39**	**15,635.82**	**16,684.49**	**15,825.08**	**14,493.78**	**14,466.27**
CF_4	2.60	2.22	2.06	2.02	1.81	1.82	1.93	1.76	1.53	1.52
C_2F_6	0.40	0.37	0.35	0.37	0.37	0.42	0.45	0.47	0.50	0.50
C_3F_8	0.00	0.00	0.00	0.00	0.00	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO
C_4F_{10}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO
c-C_4F_8	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO
C_5F_{12}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO
C_6F_{14}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO
Unspecified mix of listed PFCs[20] - ($Gg CO_2$ equivalent)	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO
Emissions of SF_6[20] - ($Gg CO_2$ equivalent)	**34,564.95**	**32,548.69**	**30,632.32**	**35,096.22**	**32,404.81**	**27,749.30**	**31,329.08**	**28,748.02**	**23,840.12**	**23,438.35**
SF_6	1.45	1.38	1.28	1.47	1.36	1.16	1.31	1.20	1.00	0.98

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (HFCs, PFCs and SF_6)
(Sheet 4 of 5)
(Part 2 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg					%
Emissions of HFCs[20] - ($Gg CO_2$ equivalent)	**101,239.00**	**98,642.84**	**106,169.33**	**105,594.75**	**119,091.97**	**234.98**
HFC-23	2.57	1.71	1.71	1.08	1.36	-54.75
HFC-32	0.44	0.46	0.50	0.56	0.63	100.00
HFC-41	IE,NA,ND	IE,NA,ND	IE,NA,ND	IE,NA,ND	IE,NA,ND	0.00
HFC-43-10mee	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	0.00
HFC-125	4.01	4.39	4.79	5.26	5.82	100.00
HFC-134	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	0.00
HFC-134a	34.95	38.20	41.17	43.66	47.39	100.00
HFC-152a	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,NE,ND	0.00
HFC-143	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	0.00
HFC-143a	2.16	2.65	3.20	3.83	4.56	100.00
HFC-227ea	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	0.00
HFC-236fa	0.21	0.28	0.34	0.37	0.37	100.00
HFC-245ca	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	C,IE,NA,ND	0.00
Unspecified mix of listed HFCs[21] - ($Gg CO_2$ equivalent)	4,647.92	4,501.66	4,563.99	4,641.82	5,287.85	1,247.35
Emissions of PFCs[21] - ($Gg CO_2$ equivalent)	**13,891.62**	**7,556.96**	**8,774.61**	**7,119.14**	**6,426.97**	**-68.87**
CF_4	1.52	0.74	0.88	0.67	0.56	-78.53
C_2F_6	0.42	0.29	0.32	0.28	0.29	-27.83
C_3F_8	0.02	0.01	0.01	0.01	0.01	1,268.84
C_4F_{10}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,NA,NE,NO	0.00
c-C_4F_8	C,IE,NA,NE,NO	C,IE,NA,NE,NO	0.01	0.01	0.01	100.00
C_5F_{12}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,NA,NE,NO	0.00
C_6F_{14}	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,IE,NA,NE,NO	C,NA,NE,NO	0.00
Unspecified mix of listed PFCs[21] - ($Gg CO_2$ equivalent)	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	0.00
Emissions of SF_6[20] - ($Gg CO_2$ equivalent)	**19,557.46**	**18,676.05**	**17,762.52**	**17,898.55**	**17,454.45**	**-49.50**
SF_6	0.82	0.78	0.74	0.75	0.73	-49.50

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (SUMMARY)
(Sheet 5 of 5)
(Part 1 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS EMISSIONS	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg CO_2 equivalent									
CO_2 emissions (including net CO_2 from LULUCF)[1]	4,894,881.78	4,053,321.56	4,185,890.35	4,435,337.16	4,523,813.55	4,710,402.72	4,904,878.32	4,939,596.13	4,876,134.41	4,929,347.08
CO_2 emissions (excluding net CO_2 from LULUCF)[1]	5,805,254.88	4,961,857.00	5,057,696.60	5,187,306.61	5,271,653.98	5,325,289.59	5,508,728.27	5,580,868.38	5,620,176.12	5,695,039.42
CH_4	618,063.64	618,175.60	618,840.88	606,887.16	612,386.78	608,945.43	599,002.82	588,825.41	579,475.17	568,972.00
N_2O	394,880.95	409,620.24	385,452.73	450,629.23	404,136.58	454,233.47	462,888.38	420,488.34	440,624.59	419,369.57
HFCs	35,551.51	31,893.24	37,110.47	36,712.60	41,404.53	51,441.45	66,072.83	75,491.05	95,056.44	93,632.22
PFCs	20,644.70	17,818.50	16,586.06	16,534.45	15,171.39	15,635.82	16,684.49	15,825.08	14,495.78	14,466.27
SF_6	34,564.95	32,940.69	30,632.32	35,096.22	32,404.81	27,749.30	31,329.08	28,748.02	23,840.12	23,428.35
Total (including net CO_2 from LULUCF)[2]	**5,198,587.53**	**5,163,569.83**	**5,273,712.81**	**5,581,196.83**	**5,629,317.64**	**5,868,408.20**	**6,080,855.93**	**6,068,974.03**	**6,029,624.51**	**6,049,215.49**
Total (excluding net CO_2 from LULUCF)[2,3]	**6,108,960.63**	**6,072,085.27**	**6,146,319.06**	**6,333,166.27**	**6,377,158.07**	**6,483,395.07**	**6,686,705.88**	**6,710,246.28**	**6,773,666.22**	**6,814,907.83**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg CO_2 equivalent									
1. Energy	5,148,310.53	5,115,596.96	5,212,562.19	5,335,403.07	5,415,571.48	5,466,523.41	5,655,753.34	5,716,343.59	5,752,269.19	5,822,264.53
2. Industrial Processes	301,106.47	281,597.15	281,481.18	284,150.97	294,071.53	305,874.25	321,516.51	327,448.97	335,054.48	327,471.02
3. Solvent and Other Product Use	4,300.25	4,188.79	3,941.89	4,479.42	4,479.42	4,479.42	4,479.42	4,766.04	4,766.04	4,766.04
4. Agriculture	439,568.46	453,509.06	429,487.72	489,526.15	443,456.07	492,994.78	496,789.12	457,325.58	483,223.40	463,084.25
5. Land Use, Land-Use Change and Forestry[3]	-904,695.77	-902,752.80	-866,772.51	-745,933.21	-741,541.75	-608,739.52	-597,452.85	-634,806.29	-737,507.47	-759,025.40
6. Waste	208,997.59	211,438.67	213,012.35	213,760.43	213,280.89	207,275.86	203,770.39	197,896.14	191,818.87	190,655.07
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (including LULUCF)[2]	**5,198,587.53**	**5,163,569.83**	**5,273,712.81**	**5,581,196.83**	**5,629,317.64**	**5,868,408.20**	**6,080,855.93**	**6,068,974.03**	**6,029,624.51**	**6,049,215.49**

TABLE 10 EMISSION TRENDS (SUMMARY)
(Sheet 5 of 5)
(Part 2 of 2)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS EMISSIONS	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg CO_2 equivalent					(%)
CO_2 emissions including net CO_2 from LULUCF[1]	5,104,958.23	5,027,264.79	5,047,258.39	5,102,829.71	5,207,890.25	27.18
CO_2 emissions excluding net CO_2 from LULUCF[1]	5,864,464.88	5,795,192.22	5,815,888.98	5,877,677.37	5,987,984.41	19.63
CH_4	566,940.92	560,258.94	559,804.46	564,371.10	556,737.49	-9.92
N_2O	416,207.67	412,838.33	407,398.81	386,076.78	388,713.91	-2.07
HFCs	101,239.00	98,642.84	106,169.33	105,994.75	119,091.97	254.98
PFCs	13,892.62	7,536.96	8,774.61	7,119.14	6,426.97	-68.87
SF_6	19,557.46	18,676.05	17,762.52	17,808.53	17,454.45	-49.50
Total (including net CO_2 from LULUCF)[2]	**6,222,795.90**	**6,125,139.91**	**6,147,158.12**	**6,184,290.01**	**6,294,315.04**	**21.08**
Total (excluding net CO_2 from LULUCF)[2, 6]	**6,982,302.55**	**6,893,127.35**	**6,915,796.70**	**6,959,137.68**	**7,074,409.20**	**15.80**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	Change from base to latest reported year
	Gg CO_2 equivalent					(%)
1. Energy	5,994,287.86	5,931,601.78	5,944,647.79	6,009,767.97	6,108,192.96	18.64
2. Industrial Processes	329,589.05	300,725.53	310,949.28	304,102.08	320,656.33	6.49
3. Solvent and Other Product Use	4,766.04	4,766.04	4,766.04	4,766.04	4,766.04	10.85
4. Agriculture	458,458.85	463,383.11	457,769.00	439,089.67	440,124.56	0.13
5. Land Use, Land-Use Change and Forestry[7]	-753,132.79	-761,750.57	-762,249.18	-768,270.68	-775,254.52	-14.55
6. Waste	188,846.89	186,414.02	191,275.18	194,834.93	193,831.69	-7.70
7. Other	NA	NA	NA	NA	NA	0.00
Total (including LULUCF)[7]	**6,222,795.90**	**6,125,139.91**	**6,147,158.12**	**6,184,290.01**	**6,294,315.04**	**21.08**

[1] The column "Base year" should be filled in only by those Parties with economies in transition that use a base year different from 1990 in accordance with the relevant decisions of the COP. For those Parties, this different base year is used to calculate the percentage change in the final column of this table.

[2] Fill in net emissions/removals as reported in table Summary 1.A. For the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+).

[3] The information in these rows is requested to facilitate comparison of data, because Parties differ in the way they report CO_2 emissions and removals from LULUCF.

[4] Enter actual emissions estimates. If only potential emissions estimates are available, these should be reported in this table and an indication for this should be provided in the documentation box. Only in these rows are the emissions expressed as CO_2 equivalent emissions.

[5] In accordance with the UNFCCC reporting guidelines, HFC and PFC emissions should be reported for each relevant chemical. However, if it is not possible to report values for each chemical (i.e., mixtures, confidential data, lack of disaggregation), this row could be used for reporting aggregate figures for HFCs and PFCs, respectively. Note that the unit used for this row is Gg of CO_2 equivalent and that appropriate notation keys should be entered in the cells for the individual chemicals.

[6] These totals will differ from the totals reported in table Summary 2 if Parties report non-CO_2 emissions from LULUCF.

[7] Includes net CO_2, CH_4 and N_2O from LULUCF.

Documentation box:
- Parties should provide detailed explanations on emissions trends in Chapter 2: Trends in Greenhouse Gas Emissions and, as appropriate, in the corresponding Chapters 3 - 9 of the NIR. Use this documentation box to provide references to relevant sections.
- Use the documentation box to provide explanations if potential emissions are reported.

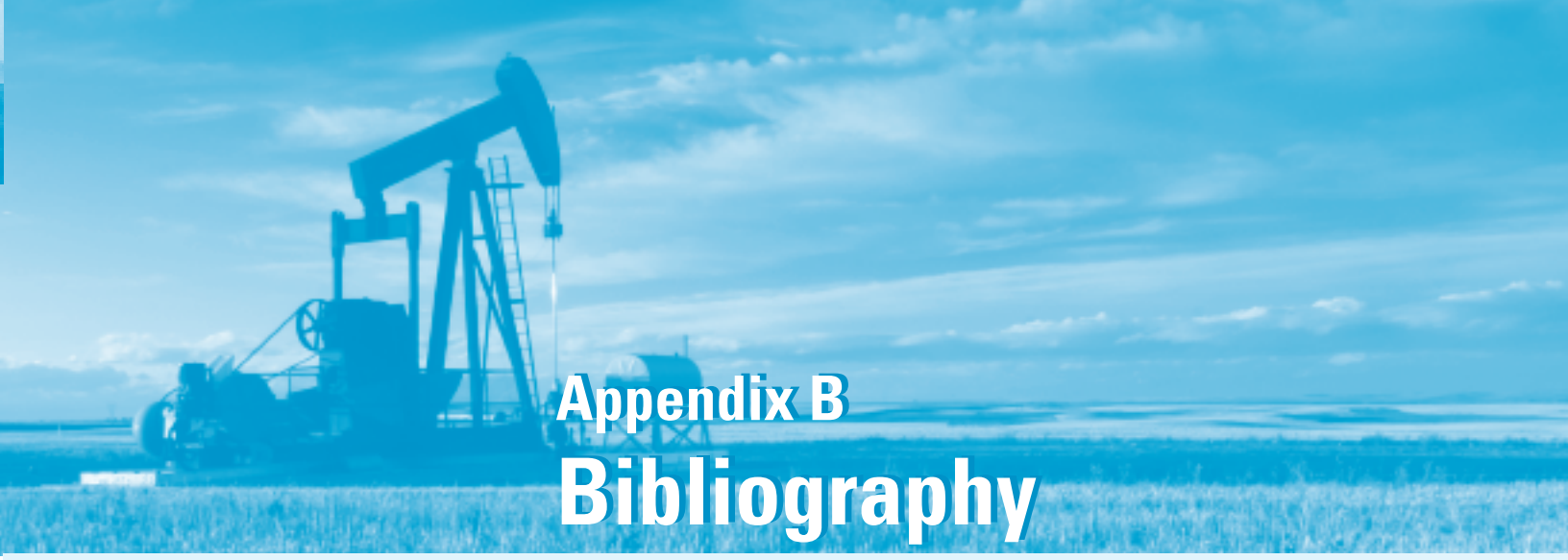
SUMMARY 2 SUMMARY REPORT FOR CO_2 EQUIVALENT EMISSIONS
(Sheet 1 of 1)

Inventory 2004
Submission 2006 v1.1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	Gg CO_2 equivalent						
Total (Net Emissions) [3]	**5,207,890.25**	**556,737.49**	**386,713.91**	**119,091.97**	**6,426.97**	**17,454.45**	**6,294,315.04**
1. Energy	**5,835,334.67**	**215,821.24**	**57,037.05**				**6,108,192.96**
A. Fuel Combustion (Sectoral Approach)	5,829,300.81	9,378.42	57,037.05				5,895,716.28
1. Energy Industries	2,290,619.61	702.00	9,374.38				2,300,695.98
2. Manufacturing Industries and Construction	863,461.40	2,327.16	4,224.98				870,013.53
3. Transport	1,825,631.34	2,650.01	41,359.18				1,869,640.54
4. Other Sectors	595,585.26	3,606.62	1,142.48				600,334.36
5. Other	254,003.20	92.64	936.03				255,031.87
B. Fugitive Emissions from Fuels	6,033.86	206,442.82	IE,NA,NE				212,476.67
1. Solid Fuels	NE	61,975.27	NE				61,975.27
2. Oil and Natural Gas	6,033.86	144,467.54	IE,NA,NE				150,501.40
2. Industrial Processes	**152,649.54**	**2,670.47**	**22,268.73**	**119,091.97**	**6,426.97**	**17,454.45**	**320,654.33**
A. Mineral Products	70,163.13	IE	IE				70,163.13
B. Chemical Industry	24,758.35	1,625.59	22,360.73	IE,NA	IE,NA	IE,NA	48,744.67
C. Metal Production	57,728.26	1,044.88	IE,NA	IE,NA	2,848.15	2,704.95	64,326.24
D. Other Production	NE						NE
E. Production of Halocarbons and SF_6				15,600.73	NA,NE	NA,NE	15,600.73
F. Consumption of Halocarbons and SF_6 [2]				103,491.24	3,578.82	14,749.50	121,819.56
G. Other	NA,NO	NA,NO	NA,NO	NA	NA	NA	NA,NO
3. Solvent and Other Product Use	**NA,NE**		**4,766.04**				**4,766.04**
4. Agriculture		**160,438.74**	**279,685.80**				**440,124.54**
A. Enteric Fermentation		112,609.58					112,609.58
B. Manure Management		39,584.41	17,684.43				57,068.84
C. Rice Cultivation		7,567.75					7,567.75
D. Agricultural Soils [3]		NA,NE	261,486.40				261,486.40
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		877.00	514.97				1,391.97
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry [4]	**-780,094.17**	**NA,NE**	**6,839.65**				**-773,254.52**
A. Forest Land	-420,195.58	NA,NE	391.87				-419,803.71
B. Cropland	-31,759.51	NA,NE	IE,NA,NE				-31,759.51
C. Grassland	-13,859.92	NA,NE	NA,NE				-13,859.92
D. Wetlands	NA,NE	NA,NE	NA,NE				NA,NE
E. Settlements	-97,511.28	NA,NE	6,447.77				-90,863.51
F. Other Land	NE	NE	NE				NE
G. Other		NE	NE				-216,967.86
6. Waste	**IE,NA**	**177,807.05**	**16,024.64**				**193,831.69**
A. Solid Waste Disposal on Land	NA	140,888.15					140,888.15
B. Waste-water Handling		36,918.90	16,024.64				52,943.54
C. Waste Incineration	IE	NE	IE				IE,NE
D. Other	NA	NA	IE				IE,NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [4]							
International Bunkers	94,408.89	105.40	853.72				95,458.00
Aviation	59,911.60	34.69	588.63				60,534.92
Marine	34,587.29	70.71	265.09				34,923.08
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**211,229.93**						**211,229.93**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	7,067,569.56
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	6,294,315.04

[1] For CO_2 from Land Use, Land-use Change and Forestry the net emissions/removals are to be reported. For the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+).
[2] Actual emissions should be included in the national totals. If no actual emissions were reported, potential emissions should be included.
[3] Parties which previously reported CO_2 from soils in the Agriculture sector should note this in the NIR.
[4] See footnote 8 to table Summary 1.A.
[5] These totals will differ from the totals reported in table 10, sheet 3 if Parties report non-CO_2 emissions from LULUCF.



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