Executive Summary

Introduction

U.S. Anthropogenic Greenhouse Gas Emissions, 1990-2000

	Carbon Equivalent
Estimated 2000 Emissions (Million Metric Tons)	1,906.3
Change Compared to 1999 (Million Metric Tons)	46.1
Change from 1999 *(Percent)*	*2.5%*
Change Compared to 1990 (Million Metric Tons)	228.4
Change from 1990 *(Percent)*	*13.6%*
Average Annual Increase, 1990-2000 *(Percent)*	*1.3%*

U.S. emissions of greenhouse gases in 2000 totaled 1,906 million metric tons carbon equivalent, 2.5 percent more than in 1999 (1,860 million metric tons carbon equivalent). The increase from 1999 to 2000 is nearly double the 1.3-percent average annual growth rate of total U.S. greenhouse gas emissions from 1990 to 2000 and the 1.3-percent increase from 1998 to 1999. The increase from 1999 to 2000 is attributed to strong growth in carbon dioxide emissions due to a return to more normal weather, decreased hydroelectric power generation that was replaced by fossil-fuel power generation, and strong economic growth (a 4.1-percent increase in gross domestic product).

U.S. greenhouse gas emissions in 2000 were about 14 percent higher than 1990 emissions (1,678 million metric tons carbon equivalent). Since 1990, U.S. emissions have increased slightly faster than the average annual growth in population (1.2 percent) but more slowly than the growth in energy consumption (1.6 percent), electric power generation (2.3 percent), or gross domestic product (3.2 percent).

Table ES1 shows trends in emissions of the principal greenhouse gases, measured in million metric tons of gas. In Table ES2, the value shown for each gas is weighted by its global warming potential (GWP), which is a measure of "radiative forcing." This concept, developed by the Intergovernmental Panel on Climate Change (IPCC), provides a comparative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.[1]

In 2001, the IPCC Working Group I released its Third Assessment Report, *Climate Change 2001: The Scientific Basis*.[2] Among other things, the Third Assessment Report updated a number of the GWP estimates that appeared in the IPCC's Second Assessment Report.[3] The GWPs published in the Third Assessment Report

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990-2000
(Million Metric Tons of Gas)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Carbon Dioxide	4,969.4	4,917.7	5,013.0	5,130.4	5,224.4	5,273.5	5,454.8	5,533.0	5,540.0	5,630.7	5,805.5
Methane	31.7	31.9	31.8	31.0	31.0	31.1	29.9	29.6	28.9	28.7	28.2
Nitrous Oxide	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2
HFCs, PFCs, and SF_6	*	*	*	*	*	*	*	*	*	*	*

*Less than 0.05 million metric tons of gas.
P = preliminary data.
Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).
Source: Estimates presented in this report.

[1] See "Units for Measuring Greenhouse Gases" on page 2, and Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).
[2] Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).
[3] Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990-2000
(Million Metric Tons Carbon Equivalent)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Carbon Dioxide	1,355	1,341	1,367	1,399	1,425	1,438	1,488	1,509	1,511	1,536	1,583
Methane	199	200	200	194	194	195	188	186	181	180	177
Nitrous Oxide	94	96	98	98	106	101	101	99	99	100	99
HFCs, PFCs, and SF_6	30	28	29	30	32	35	39	42	46	45	47
Total	**1,678**	**1,665**	**1,694**	**1,722**	**1,757**	**1,770**	**1,815**	**1,836**	**1,836**	**1,860**	**1,906**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).

Sources: **Emissions:** Estimates presented in this report. **Global Warming Potentials:** Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), pp. 38 and 388-389.

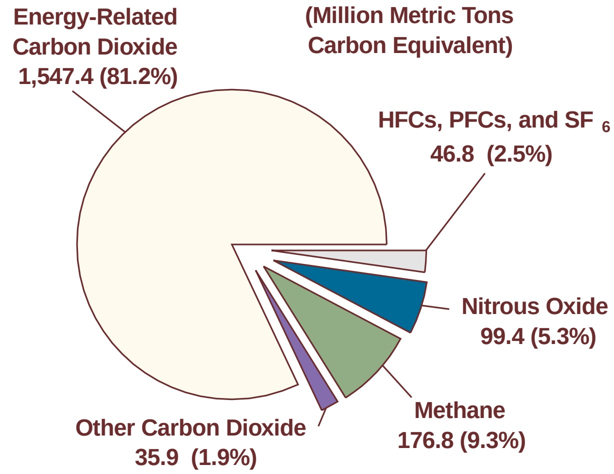
were used for the calculation of carbon-equivalent emissions for this report. For a discussion of GWPs and a comparison of U.S. carbon-equivalent emissions calculated using the GWPs from the IPCC's Third and Second Assessment Reports, see Chapter 1, page 12. Generally, total U.S. carbon-equivalent emissions are 0.6 percent higher when the GWPs from the Third Assessment Report are used.

During 2000, 81.2 percent of total U.S. greenhouse gas emissions consisted of carbon dioxide from the combustion of fossil fuels such as coal, petroleum, and natural gas. U.S. emissions trends are driven largely by trends in fossil energy consumption. In recent years, national energy consumption, like emissions, has grown relatively slowly, with year-to-year deviations from trend growth caused by weather-related phenomena, fluctuations in business cycles, changes in the fuel mix for electric power generation, and developments in domestic and international energy markets.

Other 2000 U.S. greenhouse gas emissions include carbon dioxide from non-combustion sources (1.9 percent of total U.S. greenhouse gas emissions), methane (9.3 percent), nitrous oxide (5.3 percent), and other gases (2.5 percent) (Figure ES1). Methane and nitrous oxide emissions are caused by the biological decomposition of various waste streams and fertilizer, fugitive emissions from chemical processes, fossil fuel production and combustion, and many smaller sources. The other gases include hydrofluorocarbons (HFCs), used primarily as refrigerants; perfluorocarbons (PFCs), released as fugitive emissions from aluminum smelting and also used in semiconductor manufacture; and sulfur hexafluoride (SF_6), used as an insulator in utility-scale electrical equipment.

The Kyoto Protocol, drafted in December 1997 under the auspices of the United Nations Framework Convention on Climate Change, raised the public profile of climate change issues in the United States in general, and of emissions estimates in particular. This report, required by Section 1605(a) of the Energy Policy Act of 1992,

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2000



Source: EIA estimates presented in this report.

provides estimates of U.S. emissions of greenhouse gases, as well as information on the methods used to develop the estimates.

Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions in 2000 is 1,583 million metric tons carbon equivalent—3.1 percent higher than in 1999 and accounting for 83 percent of total U.S. greenhouse gas emissions. The 3.1-percent growth rate in 2000 is the second highest for the 1990 to 2000 period, with only the 3.4-percent growth rate in 1996 being higher. Although short-term changes in carbon dioxide emissions can result from temporary variations in weather, power generation fuel mixes, and the economy, in the longer term their growth is driven by population, energy use, and income, as well as the "carbon intensity" of energy use (carbon dioxide emissions per unit of energy consumed).

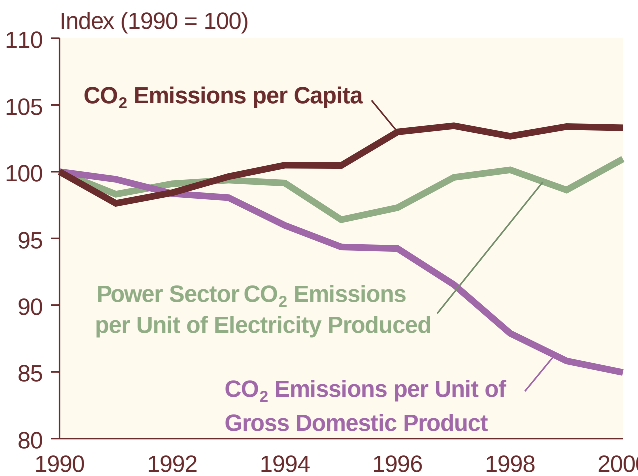
Figure ES2 illustrates some recent U.S. trends in carbon dioxide emissions and energy consumption. Although annual carbon dioxide emissions per dollar of GDP have fallen by 15 percent since 1990, carbon dioxide emissions per capita have risen by 3 percent. The combination of increasing population growth and rising carbon dioxide emissions per capita results in increased aggregate carbon dioxide emissions per year during the 1990 to 2000 time frame. Carbon dioxide emissions per unit of net electricity generation, after initially falling during the early to mid-1990s, have increased to above the 1990 level. The upturn in this measure from 1999 to 2000 helps explain the high 2000 growth rate in carbon dioxide emissions.

Figure ES3 illustrates trends in carbon dioxide emissions by energy consumption sector. In general, emissions have increased in each of the four sectors since 1990. An exception to the general upward trend was 1990-1991, when economic recession and higher oil prices following the Iraqi invasion of Kuwait led to a 1.0-percent decrease in national carbon dioxide emissions in 1991. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2000 period were 2.4 percent for the commercial sector, 2.0 percent for the residential sector and 1.8 percent for the transportation sector, all higher than the 1.6-percent average for total U.S. carbon dioxide emissions during the 1990-2000 period. For the industrial sector, however, annual growth in carbon dioxide emissions has averaged only 0.3 percent. Industrial sector carbon dioxide emissions, which are relatively sensitive to economic fluctuations, declined by 2.5 percent in 1991 during the economic recession and dipped again in 1998 in the wake of the Asian economic slowdown.

Carbon dioxide emissions from the U.S. electric power sector (which includes cogeneration) in 2000 are estimated at 642 million metric tons carbon equivalent, 4.7 percent higher than the 1999 level. The 2000 increase is almost double the 1990-2000 average increase of 2.4 percent per year. Contributing to the relatively large increase in 2000 was a 4.2-percent increase in fossil fuel use for electricity generation, including a 4.3-percent increase in coal-fired generation and a 7.1-percent increase in natural-gas-fired generation. Electricity generation from renewable fuels was down by 11 percent, including a 14-percent drop in hydroelectric generation. On the demand side, electricity-related emissions in the residential sector were 5.6 percent higher in 2000 than in 1999, and in the commercial sector they were 4.9 percent higher.[4] Although summer cooling degree-days were 4.4 percent above normal in 2000, air conditioning usage was lower than in 1999, when cooling degree-days were 7.3 percent above normal.

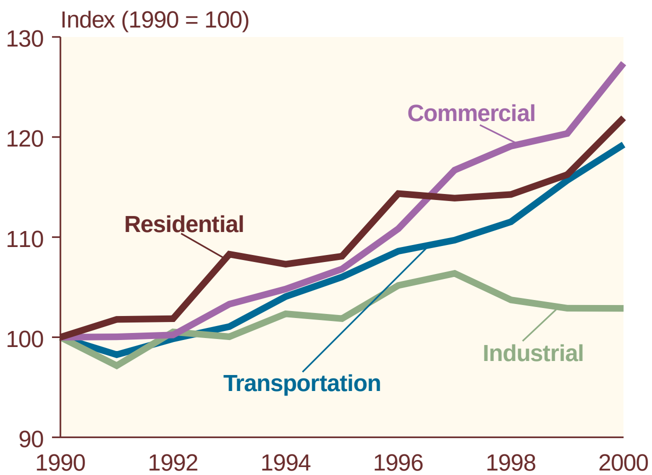
In addition to electricity-related emissions, direct use of energy fuels in the residential, commercial, industrial, and transportation sectors produces carbon dioxide emissions. In the residential and commercial sectors, consumption of winter heating fuels, particularly natural gas, was higher in 2000 than in 1999 as a result of winter weather that was 7.0 percent colder than in 1999.[5]

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2000



Sources: Estimates presented in this report.

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2000



Sources: Estimates presented in this report.

[4]The sectoral shares of electricity-related carbon dioxide emissions are based on the shares of total electric utility power sales purchased in each sector.

[5]Population-weighted heating degree-days in 2000 were 7.0 percent higher than in 1999. See Energy Information Administration, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, August 2000), Table 1.7.

Carbon dioxide emissions from the direct combustion of fuels (primarily natural gas) increased by 3.5 percent in the residential sector and by 8.8 percent in the commercial sector. Overall, carbon dioxide emissions in the residential and commercial sectors, at a combined 581 million metric tons carbon equivalent and 37.2 percent of total carbon dioxide emissions, grew by 5.3 percent in 2000.

Energy-related carbon dioxide emissions in the industrial sector in 2000 are estimated at 466 million metric tons carbon equivalent—which is equal to the level of emissions in 1999. The lack of growth in industrial emissions is noteworthy because, historically, industrial energy consumption and carbon dioxide emissions have been more sensitive to economic growth than to the weather, and 2000 was a year of solid economic growth (4.1 percent). Industrial energy consumption and emissions are concentrated in a few industries, however, and their performance may have more influence on emissions than does the performance of the industrial sector as a whole. Six industry groups—petroleum refining, chemicals and related products, primary metals, paper, food, and stone, clay and glass—collectively account for 79.6 percent of carbon dioxide emissions from manufacturing and 68.2 percent of carbon dioxide emissions from the industrial sector.

In 2000 the six energy-intensive industry groups appeared to be still recovering from downturns from their 1997 growth rates. Their 2000 annual growth rates were lower than those for the overall economy (4.1 percent), the industrial sector (5.6 percent), and the manufacturing component of industrial production (6.1 percent). For the six energy-intensive industries, 2000 growth rates were 2.5 percent (primary metals), 1.8 percent (chemicals), -0.9 percent (paper), 2.3 percent (stone, clay and glass), 1.6 percent (petroleum products), and 1.9 percent (food). The industries that grew rapidly in 2000 were primarily those with lower energy intensities, including computer equipment, which grew by 43 percent, and semiconductors and related components, which grew by 76 percent.[6]

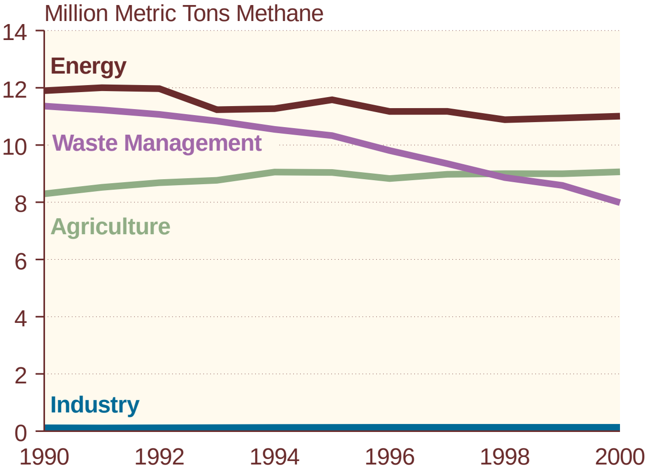
Carbon dioxide emissions in the transportation sector, at 515 million metric tons carbon equivalent, were 3.1 percent higher in 2000 than in 1999. Gasoline consumption, which accounted for 59 percent of transportation sector emissions, grew by 0.6 percent. Emissions from jet fuel use grew by 3.4 percent, and emissions from residual fuel (used mostly by oceangoing ships) grew by 35.9 percent. Emissions from distillate use increased by 4.6 percent, as a healthy U.S. economy led to greater consumption of diesel fuel by freight trucks.

Methane

U.S. emissions of methane in 2000 were 1.6 percent lower than in 1999, at 28.2 million metric tons of methane or 177 million metric tons carbon equivalent. The decline resulted primarily from an increase in methane recovery for energy use at landfills and, to a lesser extent, from reductions in emissions from coal mining and petroleum systems.

Methane emissions come from four categories of sources, three major and one minor. The major sources are energy, waste management, and agriculture, and the minor source is industrial processes. The three major sources accounted for 39, 28, and 32 percent, respectively, of total 2000 U.S. emissions of methane, or approximately 9 percent of the Nation's total carbon-equivalent greenhouse gas emissions. The major sources of anthropogenic methane emissions are illustrated in Figure ES4. Methane emissions from the anaerobic decomposition of municipal solid waste in landfills, part of the waste management source category, had been declining slowly before 2000 as a consequence of a reduction in the volume of waste landfilled and a gradual increase in the volumes of landfill gas captured. Emissions of methane resulting from waste management decreased by 7.0 percent in 2000.

Figure ES4. U.S. Methane Emissions by Source, 1990-2000



Sources: Estimates presented in this report.

[6] All industrial and manufacturing growth rates are taken from U.S. Federal Reserve Board, "G17 Historical Data: Industrial Production and Capacity Utilization." Although the Federal Reserve Board, in calculating indexes, bases its estimates on two main types of source data, output measured in physical units and data on inputs to the production process, it also adjusts its indexes on the basis of technological improvements in factor productivity and outputs. This could be particularly important for indexes related to computers and semiconductors, for which productivity and quality of outputs have improved dramatically over time.

Methane recovery for energy at U.S. landfills rose from 2.2 million metric tons in 1999 to 2.5 million metric tons in 2000 due to the lingering effects of Section 29 of the Windfall Profits Tax Act of 1980. To be eligible for the tax credit, methane recovery systems at landfills must have been operational by June 30, 1998. The last recovery projects installed by the tax credit deadline continued to ramp up in 2000. Additionally, for the first time in 40 years, U.S. coal production fell for a second consecutive year as coal imports increased by 37 percent and electric utilities drew down stocks to meet increasing demand,[7] lowering methane emissions from coal mining and post-mining activities by about 0.1 million metric tons. Domestic oil production also declined in 2000, and methane emissions from petroleum systems decreased accordingly.

Methane is also emitted as a byproduct of fossil energy production and transport. Methane can leak from natural gas production and distribution systems and is also emitted during coal production. Energy-related methane emissions were essentially unchanged in 2000 at 11.0 million metric tons. Agricultural emissions have several sources but are dominated by emissions from domestic livestock, including the animals themselves and the anaerobic decomposition of their waste. Agricultural emissions increased by about 0.8 percent in 2000.

The estimates for methane emissions are more uncertain than those for carbon dioxide. U.S. methane emissions do not necessarily increase with growth in energy consumption or the economy. Energy-related methane emissions are strongly influenced by coal production from a relatively restricted number of mines; agricultural emissions are influenced in part by the public's consumption of milk and beef and in part by animal husbandry practices; and livestock and municipal waste emissions are influenced by husbandry and waste management practices.

Nitrous Oxide

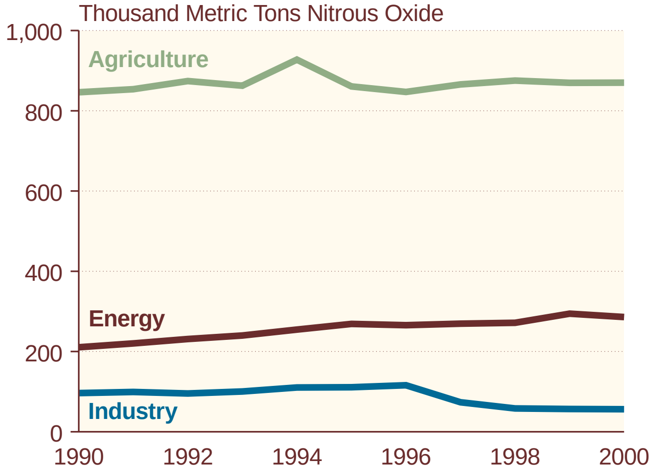
U.S. nitrous oxide emissions decreased by 0.6 percent from 1999 to 2000, to 99 million metric tons carbon equivalent. Nitrous oxide accounts for 5 percent of U.S. GWP-weighted greenhouse gas emissions. Emissions estimates for nitrous oxide are more uncertain than those for either carbon dioxide or methane, because nitrous oxide is not systematically measured and many sources of nitrous oxide emissions, including nitrogen fertilization of soils and motor vehicles, require a significant number of assumptions to arrive at estimated emissions.

U.S. nitrous oxide emissions include one large class of sources and two small classes (Figure ES5). Agricultural sources account for about 70 percent of nitrous oxide emissions, and emissions associated with nitrogen fertilization of soils account for 73 percent of agricultural emissions. In 2000, estimated nitrous oxide emissions from nitrogen fertilization of soils increased by 0.2 percent from 1999. Emissions associated with fossil fuel use account for another 23 percent of nitrous oxide emissions, of which about 83 percent comes from mobile sources, principally motor vehicles equipped with catalytic converters. The balance of nitrous oxide emissions are caused by certain chemical manufacturing and wastewater treatment processes. The most striking trend in U.S. nitrous oxide emissions has been a 52-percent decline from 1996 levels of industrial emissions of nitrous oxide after the implementation of emissions controls at an adipic acid plant operated by the DuPont Corporation.

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF_6 are three classes of engineered gases that account for 2.5 percent of U.S. GWP-weighted emissions of greenhouse gases. At 46.8 million metric tons carbon equivalent in 2000, their emissions were 4.5 percent higher than in 1999. The 2000 increase in emissions of the engineered gases was caused almost entirely

Figure ES5. U.S. Nitrous Oxide Emissions by Source, 1990-2000



Sources: Estimates presented in this report.

[7]Energy Information Administration, *U.S. Coal Supply and Demand: 2000 Review*, web site http://www.eia.doe.gov/cneaf/coal/page/special/feature.html.

by an increase in emissions of HFCs (8.3 percent) as emissions of PFCs and SF_6 fell by 3.7 percent and 4.3 percent, respectively. The increase in HFC emissions in 2000 may be attributable in part to maturing markets for chlorofluorocarbon substitutes and increasing awareness of the potential for recycling these gases.

At 28.1 million metric tons carbon equivalent, emissions of HFCs make up the majority of this category, followed by PFCs at 8.7 million metric tons carbon equivalent and SF_6 at 5.5 million metric tons carbon equivalent. Another group of engineered gases, consisting of other HFCs, other PFCs, and perfluoropolyethers (PFPEs), includes HFC-152a, HFC-227ea, HFC-4310mee, and a variety of PFCs and PFPEs. They are grouped together in this report to protect confidential data. In 2000, their combined emissions totaled 4.4 million metric tons carbon equivalent. Emissions in this "other" group in 2000 were 10.5 percent higher than in 1999. Since 1990, HFC emissions from U.S. sources have increased by 181.4 percent, PFC emissions have decreased by 14.4 percent, and SF_6 emissions have decreased by 41.4 percent.

Emissions of the high-GWP gases specified in the Kyoto Protocol are very small (at most a few thousand metric tons). On the other hand, some of the gases (including PFCs and SF_6) have atmospheric lifetimes measured in the hundreds or thousands of years, and consequently they are potent greenhouse gases with GWPs hundreds or thousands of times higher than that of carbon dioxide per unit of molecular weight. Some of the commercially produced HFCs (134a, 152a, 4310, 227ea), which are used as chlorofluorocarbon replacements, have shorter atmospheric lifetimes, ranging from 1 to 36 years.

Land Use and Forestry

Forest lands in the United States are net absorbers of carbon dioxide from the atmosphere. According to U.S. Forest Service researchers, U.S. forest land absorbs about 270 million metric tons of carbon annually, equivalent to 17.1 percent of U.S. carbon dioxide emissions. Absorption is enabled by the reversal of the extensive deforestation of the United States that occurred in the late 19th and early 20th centuries. Since then, millions of acres of formerly cultivated land have been abandoned and have returned to forest, with the regrowth of forests sequestering carbon on a large scale. The process is steadily diminishing, however, because the rate at which forests absorb carbon slows as the trees mature, and because the rate of reforestation has slowed.

Over the past several years there has been increasing interest in the United States regarding carbon sequestration in agricultural soils through changes in agricultural practices. Proponents suggest that changes in tillage practices can cause agricultural soils to move from being net sources to net sinks of carbon dioxide, and that the amounts of carbon that might be absorbed by these changes could be significant at the national level. At present, the Energy Information Administration does not have sufficient information to permit reliable estimation of national-level emissions or sequestration from this source. As more reliable information becomes available, estimates will be included in future reports.