

Executive Summary

An emissions inventory that identifies and quantifies a country's primary anthropogenic¹ sources and sinks of greenhouse gases is essential for addressing climate change. This inventory 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 contribution of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. As stated in Article 2 of the UNFCCC, “The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”²

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...”³ The United States views this report as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990 through 2011. 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 Revised 1996 Intergovernmental Panel on Climate Change (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). Additionally, the U.S. emission inventory has continued to incorporate new methodologies and data from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The use of the most recently published calculation methodologies by the IPCC, as contained in the 2006 IPCC Guidelines, is considered to improve the rigor and accuracy of this inventory and is fully in line with the prior IPCC guidance. The structure of this report is consistent with the UNFCCC guidelines for inventory reporting.⁴ For most source categories, the IPCC methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

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 that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997).

² Article 2 of the Framework Convention on Climate Change published by the UNEP/WMO Information Unit on Climate Change. See <<http://unfccc.int>>.

³ Article 4(1)(a) of the United Nations Framework Convention on Climate Change (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>>.

⁴ See <<http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf>>.

Box ES 1: Methodological Approach for Estimating and Reporting U.S. Emissions and Sinks

In following the UNFCCC requirement under Article 4.1 to develop and submit national greenhouse gas emissions inventories, the emissions and sinks presented in this report are organized by source and sink categories and calculated using internationally-accepted methods provided by the IPCC.⁵ Additionally, the calculated emissions and sinks in a given year for the United States are presented in a common manner in line with the UNFCCC reporting guidelines for the reporting of inventories under this international agreement.⁶ The use of consistent methods to calculate emissions and sinks by all nations providing their inventories to the UNFCCC ensures that these reports are comparable. In this regard, U.S. emissions and sinks reported in this inventory report are comparable to emissions and sinks reported by other countries. Emissions and sinks provided in this inventory do not preclude alternative examinations, but rather this inventory report presents emissions and sinks in a common format consistent with how countries are to report inventories under the UNFCCC. The report itself follows this standardized format, and provides an explanation of the IPCC methods used to calculate emissions and sinks, and the manner in which those calculations are conducted.

On October 30, 2009, the U.S. Environmental Protection Agency (EPA) published a rule for the mandatory reporting of greenhouse gases (GHG) from large GHG emissions sources in the United States. Implementation of 40 CFR Part 98 is referred to as the Greenhouse Gas Reporting Program (GHGRP). 40 CFR part 98 applies to direct greenhouse gas emitters, fossil fuel suppliers, industrial gas suppliers, and facilities that inject CO₂ underground for sequestration or other reasons⁷. Reporting is at the facility level, except for certain suppliers of fossil fuels and industrial greenhouse gases. The GHGRP dataset and the data presented in this inventory report are complementary and, as indicated in the respective methodological and planned improvements sections in this report's chapters, EPA is using the data, as applicable, to improve the national estimates presented in this inventory.

ES.1. Background Information

Greenhouse gases trap heat and make the planet warmer. The most important greenhouse gases directly emitted by humans include CO₂, CH₄, N₂O, and several other fluorine-containing halogenated substances. Although the direct greenhouse gases CO₂, CH₄, and N₂O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2010, concentrations of these greenhouse gases have increased globally by 39, 158, and 18 percent, respectively (IPCC 2007 and NOAA/ESLR 2009). This annual report estimates the total national greenhouse gas emissions and removals associated with human activities across the United States.

Global Warming Potentials

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or

⁵ See <<http://www.ipcc-nggip.iges.or.jp/public/index.html>>.

⁶ See <http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php>.

⁷ See <<http://www.epa.gov/climatechange/emissions/ghgrulemaking.html>> and <<http://ghgdata.epa.gov/ghgp/main.do>>.

albedo).⁸ The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

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) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO₂, and therefore GWP-weighted emissions are measured in teragrams (or million metric tons) of CO₂ equivalent (Tg CO₂ Eq.).^{9,10} All gases in this Executive Summary are presented in units of Tg CO₂ Eq.

The UNFCCC reporting guidelines for national inventories were updated in 2006,¹¹ but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2011 are consistent with estimates developed prior to the publication of the IPCC Third Assessment Report (TAR) (IPCC 2001) and the IPCC Fourth Assessment Report (AR4) (IPCC 2007). Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. All estimates are provided throughout the report in both CO₂ equivalents and unweighted units. A comparison of emission values using the SAR GWPs versus the TAR and AR4 GWPs can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in this report are listed below in Table ES-1.

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP
CO ₂	1
CH ₄ *	21
N ₂ O	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 ₂ F ₆	9,200
C ₄ F ₁₀	7,000
C ₆ F ₁₄	7,400
SF ₆	23,900

Source: IPCC (1996)

* The CH₄ GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO₂ is not included.

⁸ Albedo is a measure of the Earth's reflectivity, and is defined as the fraction of the total solar radiation incident on a body that is reflected by it.

⁹ Carbon comprises 12/44th of carbon dioxide by weight.

¹⁰ One teragram is equal to 10¹² grams or one million metric tons.

¹¹ See <<http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf>>.

Global warming potentials are not provided for CO, NO_x, NMVOCs, SO₂, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

ES.2. Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2011, total U.S. greenhouse gas emissions were 6,702.3 Tg, or million metric tons, CO₂ Eq. Total U.S. emissions have increased by 8.4 percent from 1990 to 2011, and emissions decreased from 2010 to 2011 by 1.6 percent (108.0 Tg CO₂ Eq.). The decrease from 2010 to 2011 was due to a decrease in the carbon intensity of fuels consumed to generate electricity due to a decrease in coal consumption, with increased natural gas consumption and a significant increase in hydropower used. Additionally, relatively mild winter conditions, especially in the South Atlantic Region of the United States where electricity is an important heating fuel, resulted in an overall decrease in electricity demand in most sectors. Since 1990, U.S. emissions have increased at an average annual rate of 0.4 percent. Figure ES-1 through Figure ES-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990.

Table ES-2 provides a detailed summary of U.S. greenhouse gas emissions and sinks for 1990 through 2011.

Figure ES-1: U.S. Greenhouse Gas Emissions by Gas

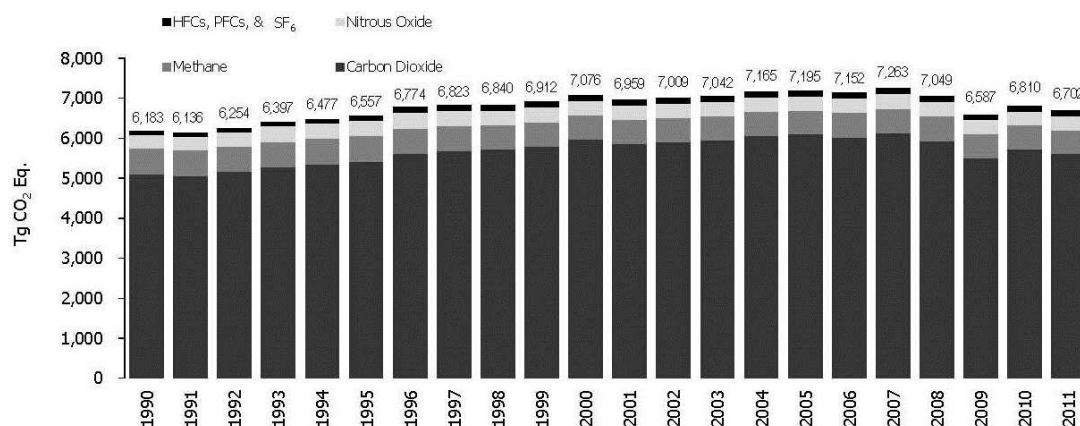


Figure ES-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

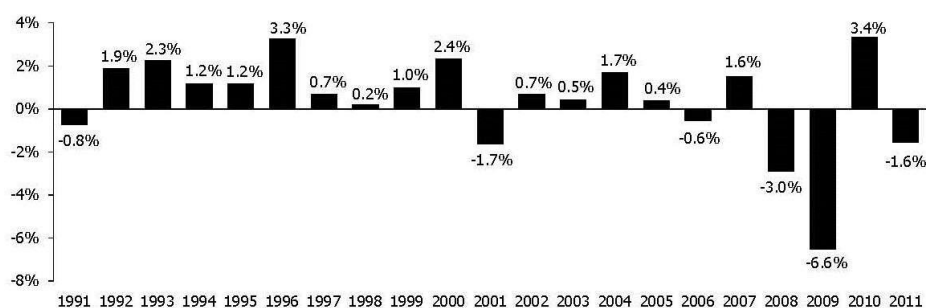


Figure ES-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990

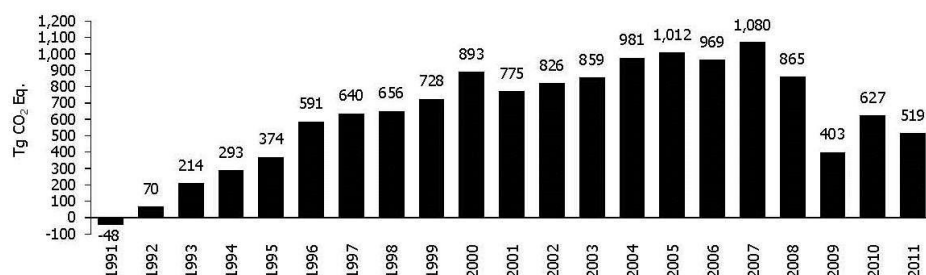


Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg or million metric tons CO₂ Eq.)

Gas/Source	1990	2005	2007	2008	2009	2010	2011
CO₂	5,108.8	6,109.3	6,128.6	5,944.8	5,517.9	5,736.4	5,612.9
Fossil Fuel Combustion	4,748.5	5,748.7	5,767.7	5,590.6	5,222.4	5,408.1	5,277.2
Electricity Generation	1,820.8	2,402.1	2,412.8	2,360.9	2,146.4	2,259.2	2,158.5
Transportation	1,494.0	1,891.7	1,904.7	1,816.0	1,749.2	1,763.9	1,745.0
Industrial	848.6	823.4	844.4	802.0	722.6	780.2	773.2
Residential	338.3	357.9	341.6	347.0	337.0	334.6	328.8
Commercial	219.0	223.5	218.9	223.8	223.4	221.8	222.1
U.S. Territories	27.9	50.0	45.2	41.0	43.8	49.6	49.7
Non-Energy Use of Fuels	117.4	142.7	134.9	139.5	124.0	132.8	130.6
Iron & Steel & Metallurgical							
Coke Production	99.8	66.7	71.3	66.8	43.0	55.7	64.3
Natural Gas Systems	37.7	29.9	30.9	32.6	32.2	32.3	32.3
Cement Production	33.3	45.2	44.5	40.5	29.0	30.9	31.6
Lime Production	11.5	14.3	14.6	14.3	11.2	13.1	13.8
Incineration of Waste	8.0	12.5	12.7	11.9	11.7	12.0	12.0
Other Process Uses of							
Carbonates	4.9	6.3	7.4	5.9	7.6	9.6	9.2
Ammonia Production	13.0	9.2	9.1	7.9	7.9	8.7	8.8
Cropland Remaining Cropland	7.1	7.9	8.2	8.6	7.2	8.4	8.1
Urea Consumption for Non-							
Agricultural Purposes	3.8	3.7	4.9	4.1	3.4	4.4	4.3
Petrochemical Production	3.4	4.3	4.1	3.6	2.8	3.5	3.5
Aluminum Production	6.8	4.1	4.3	4.5	3.0	2.7	3.3

Soda Ash Production and Consumption	2.8	3.0	2.9	3.0	2.6	2.7	2.7
Titanium Dioxide Production	1.2	1.8	1.9	1.8	1.6	1.8	1.9
Carbon Dioxide Consumption	1.4	1.3	1.9	1.8	1.8	2.2	1.8
Ferroalloy Production	2.2	1.4	1.6	1.6	1.5	1.7	1.7
Glass Production	1.5	1.9	1.5	1.5	1.0	1.5	1.3
Zinc Production	0.6	1.0	1.0	1.2	0.9	1.2	1.3
Phosphoric Acid Production	1.5	1.3	1.2	1.2	1.0	1.1	1.2
Wetlands Remaining Wetlands	1.0	1.1	1.0	1.0	1.1	1.0	0.9
Lead Production	0.5	0.6	0.6	0.5	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.1	0.2	0.2
<i>Land Use, Land-Use Change, and Forestry (Sink)^a</i>	<i>(794.5)</i>	<i>(997.8)</i>	<i>(929.2)</i>	<i>(902.6)</i>	<i>(882.6)</i>	<i>(888.8)</i>	<i>(905.0)</i>
<i>Wood Biomass and Ethanol Consumption^b</i>	<i>218.6</i>	<i>228.7</i>	<i>238.3</i>	<i>251.7</i>	<i>245.1</i>	<i>264.5</i>	<i>264.5</i>
<i>International Bunker Fuels^c</i>	<i>103.5</i>	<i>113.1</i>	<i>115.3</i>	<i>114.3</i>	<i>106.4</i>	<i>117.0</i>	<i>111.3</i>
CH₄	639.9	593.6	618.6	618.8	603.8	592.7	587.2
Natural Gas Systems	161.2	159.0	168.4	163.4	150.7	143.6	144.7
Enteric Fermentation	132.7	137.0	141.8	141.4	140.6	139.3	137.4
Landfills	147.8	112.5	111.6	113.6	113.3	106.8	103.0
Coal Mining	84.1	56.9	57.9	67.1	70.3	72.4	63.2
Manure Management	31.5	47.6	52.4	51.5	50.5	51.8	52.0
Petroleum Systems	35.2	29.2	29.8	30.0	30.5	30.8	31.5
Wastewater Treatment	15.9	16.5	16.6	16.6	16.5	16.4	16.2
Forest Land Remaining Forest Land	2.5	8.0	14.4	8.7	5.7	4.7	14.2
Rice Cultivation	7.1	6.8	6.2	7.2	7.3	8.6	6.6
Stationary Combustion	7.5	6.6	6.4	6.6	6.3	6.3	6.3
Abandoned Underground Coal Mines	6.0	5.5	5.3	5.3	5.1	5.0	4.8
Petrochemical Production	2.3	3.1	3.3	2.9	2.9	3.1	3.1
Mobile Combustion	4.6	2.4	2.1	1.9	1.8	1.8	1.7
Composting	0.3	1.6	1.7	1.7	1.6	1.5	1.5
Iron & Steel & Metallurgical Coke Production	1.0	0.7	0.7	0.6	0.4	0.5	0.6
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
<i>International Bunker Fuels^c</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>
N₂O	344.3	356.1	376.1	349.7	338.7	343.9	356.9
Agricultural Soil Management	227.9	237.5	252.3	245.4	242.8	244.5	247.2
Stationary Combustion	12.3	20.6	21.2	21.1	20.7	22.6	22.0
Mobile Combustion	44.0	36.9	29.0	25.5	22.7	20.7	18.5
Manure Management	14.4	17.1	18.0	17.8	17.7	17.8	18.0
Nitric Acid Production	18.2	16.9	19.7	16.9	14.0	16.8	15.5
Forest Land Remaining Forest Land	2.1	6.9	12.1	7.4	5.0	4.2	11.9
Adipic Acid Production	15.8	7.4	10.7	2.6	2.8	4.4	10.6
Wastewater Treatment	3.5	4.7	4.8	4.9	5.0	5.1	5.2
N ₂ O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Composting	0.4	1.7	1.8	1.9	1.8	1.7	1.7
Settlements Remaining	1.0	1.5	1.6	1.5	1.4	1.5	1.5

Settlements							
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
<i>International Bunker Fuels^c</i>	<i>0.9</i>	<i>1.0</i>	<i>1.0</i>	<i>1.0</i>	<i>0.9</i>	<i>1.0</i>	<i>1.0</i>
HFCs	36.9	115.0	120.0	117.5	112.0	121.3	129.0
Substitution of Ozone Depleting Substances ^d	0.3	99.0	102.7	103.6	106.3	114.6	121.7
HCFC-22 Production	36.4	15.8	17.0	13.6	5.4	6.4	6.9
Semiconductor Manufacture	0.2	0.2	0.3	0.3	0.2	0.4	0.3
PFCs	20.6	6.2	7.7	6.6	4.4	5.9	7.0
Semiconductor Manufacture	2.2	3.2	3.8	3.9	2.9	4.4	4.1
Aluminum Production	18.4	3.0	3.8	2.7	1.6	1.6	2.9
SF₆	32.6	15.0	12.3	11.4	9.8	10.1	9.4
Electrical Transmission and Distribution	26.7	11.1	8.8	8.6	8.1	7.8	7.0
Magnesium Production and Processing	5.4	2.9	2.6	1.9	1.1	1.3	1.4
Semiconductor Manufacture	0.5	1.0	0.8	0.9	0.7	1.0	0.9
Total	6,183.3	7,195.3	7,263.2	7,048.8	6,586.6	6,810.3	6,702.3
Net Emissions (Sources and Sinks)	5,388.7	6,197.4	6,334.0	6,146.2	5,704.0	5,921.5	5,797.3

+ Does not exceed 0.05 Tg CO₂ Eq.

^a Parentheses indicate negative values or sequestration. The net CO₂ flux total includes both emissions and sequestration, and constitutes a net sink in the United States. Sinks are only included in net emissions total.

^b Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

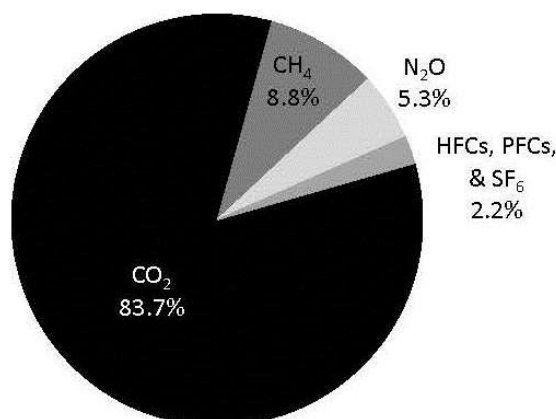
^c Emissions from International Bunker Fuels are not included in totals.

^d Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Figure ES-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2011. The primary greenhouse gas emitted by human activities in the United States was CO₂, representing approximately 83.7 percent of total greenhouse gas emissions. The largest source of CO₂, and of overall greenhouse gas emissions, was fossil fuel combustion. CH₄ emissions, which have decreased by 8.2 percent since 1990, resulted primarily from natural gas systems, enteric fermentation associated with domestic livestock, and decomposition of wastes in landfills. Agricultural soil management, mobile source fuel combustion and stationary fuel combustion were the major sources of N₂O emissions. Ozone depleting substance substitute emissions and emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. PFC emissions resulted from semiconductor manufacturing and as a by-product of primary aluminum production, while electrical transmission and distribution systems accounted for most SF₆ emissions.

Figure ES-4: 2011 Greenhouse Gas Emissions by Gas (Percentages based on Tg CO₂ Eq.)



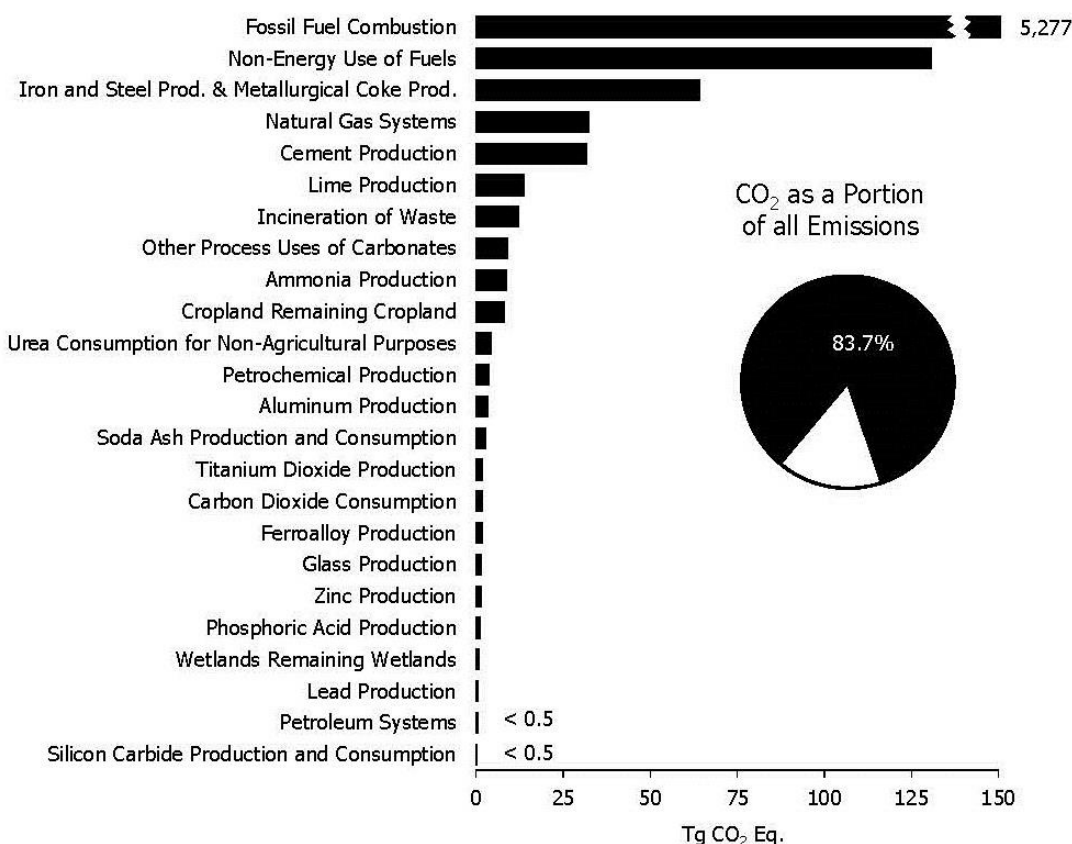
Overall, from 1990 to 2011, total emissions of CO₂ increased by 504.0 Tg CO₂ Eq. (9.9 percent), while total emissions of CH₄ decreased by 52.7 Tg CO₂ Eq. (8.2 percent), and N₂O increased by 12.6 Tg CO₂ Eq. (3.6 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, and SF₆ rose by 55.1 Tg CO₂ Eq. (61.1 percent). From 1990 to 2011, HFCs increased by 92.0 Tg CO₂ Eq. (249.3 percent), PFCs decreased by 13.6 Tg CO₂ Eq. (66.1 percent), and SF₆ decreased by 23.3 Tg CO₂ Eq. (71.3 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF₆ are significant because many of these gases have extremely high global warming potentials and, in the cases of PFCs and SF₆, 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 13.5 percent of total emissions in 2011. 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 CO₂ 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 CO₂ have risen about 39 percent (IPCC 2007 and NOAA/ESLR 2009), principally due to the combustion of fossil fuels. Within the United States, fossil fuel combustion accounted for 94.0 percent of CO₂ emissions in 2011. Globally, approximately 31,780 Tg of CO₂ were added to the atmosphere through the combustion of fossil fuels in 2010, of which the United States accounted for about 18 percent.¹² Changes in land use and forestry practices can also emit CO₂ (e.g., through conversion of forest land to agricultural or urban use) or can act as a sink for CO₂ (e.g., through net additions to forest biomass). In addition to fossil-fuel combustion, several other sources emit significant quantities of CO₂. These sources include, but are not limited to non-energy use of fuels, iron and steel production and cement production (Figure ES-5).

¹² Global CO₂ emissions from fossil fuel combustion were taken from Energy Information Administration *International Energy Statistics 2010* < <http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm> > EIA (2013).

Figure ES-5: 2011 Sources of CO₂ Emissions



Note: Electricity generation also includes emissions of less than 0.05 Tg CO₂ Eq. from geothermal-based generation.

As the largest source of U.S. greenhouse gas emissions, CO₂ from fossil fuel combustion has accounted for approximately 78 percent of GWP-weighted emissions since 1990, and is approximately 79 percent of total GWP-weighted emissions in 2011. Emissions of CO₂ from fossil fuel combustion increased at an average annual rate of 0.5 percent from 1990 to 2011. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 22 years, and (2) an overall growth in emissions from electricity generation and transportation activities. Between 1990 and 2011, CO₂ emissions from fossil fuel combustion increased from 4,748.5 Tg CO₂ Eq. to 5,277.2 Tg CO₂ Eq.—an 11.1 percent total increase over the twenty-two-year period. From 2010 to 2011, these emissions decreased by 130.9 Tg CO₂ Eq. (2.4 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO₂ emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. In the short term, the overall consumption of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants. In the long term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs) and behavioral choices (e.g., walking, bicycling, or telecommuting to work instead of driving).

Figure ES-6: 2011 CO₂ Emissions from Fossil Fuel Combustion by Sector and Fuel Type

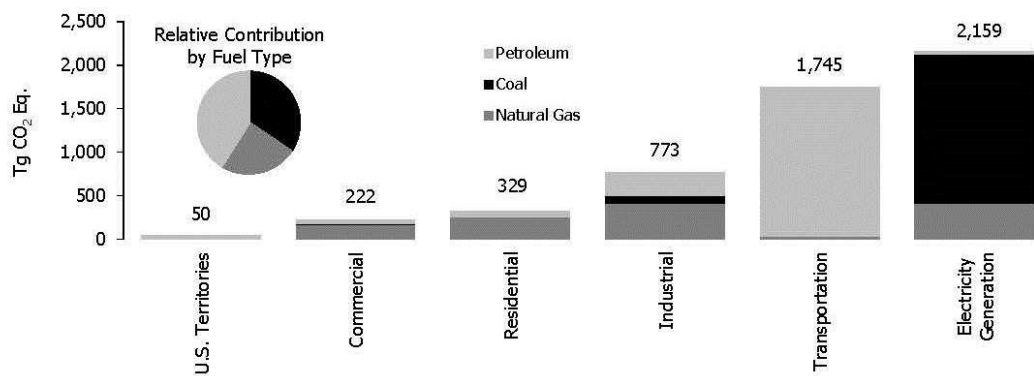
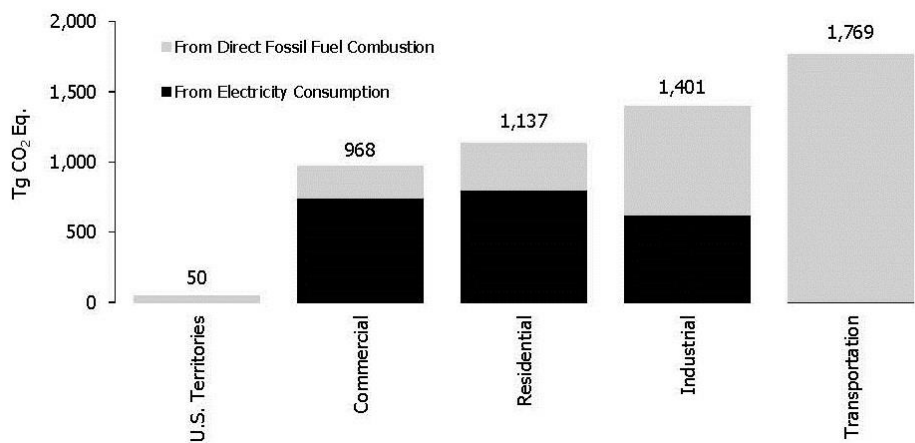


Figure ES-7: 2011 End-Use Sector Emissions of CO₂, CH₄, and N₂O from Fossil Fuel Combustion



The five major fuel consuming sectors contributing to CO₂ emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. CO₂ emissions are produced by the electricity generation sector as they consume fossil fuel to provide electricity to one of the other four sectors, or “end-use” sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector’s share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors. Figure ES-6, Figure ES-7, and Table ES-3 summarize CO₂ emissions from fossil fuel combustion by end-use sector.

Table ES-3: CO₂ Emissions from Fossil Fuel Combustion by Fuel Consuming End-Use Sector (Tg or million metric tons CO₂ Eq.)

End-Use Sector	1990	2005	2007	2008	2009	2010	2011
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Transportation	1,497.0	1,896.5	1,909.7	1,820.7	1,753.7	1,768.4	1,749.3
Combustion	1,494.0	1,891.7	1,904.7	1,816.0	1,749.2	1,763.9	1,745.0
Electricity	3.0	4.7	5.1	4.7	4.5	4.5	4.3
Industrial	1,535.3	1,560.4	1,559.9	1,499.3	1,324.6	1,421.3	1,392.1
Combustion	848.6	823.4	844.4	802.0	722.6	780.2	773.2
Electricity	686.7	737.0	715.4	697.3	602.0	641.1	618.9
Residential	931.4	1,214.7	1,205.2	1,189.9	1,123.5	1,175.0	1,125.6
Combustion	338.3	357.9	341.6	347.0	337.0	334.6	328.8
Electricity	593.0	856.7	863.5	842.9	786.5	840.4	796.9
Commercial	757.0	1,027.2	1,047.7	1,039.8	976.8	993.9	960.5
Combustion	219.0	223.5	218.9	223.8	223.4	220.6	222.1
Electricity	538.0	803.7	828.8	816.0	753.5	773.3	738.4
U.S. Territories^a	27.9	50.0	45.2	41.0	43.8	49.6	49.7
Total	4,748.5	5,748.7	5,767.7	5,590.6	5,222.4	5,408.1	5,277.2
Electricity Generation	1,820.8	2,402.1	2,412.8	2,360.9	2,146.4	2,259.2	2,158.5

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

^a Fuel consumption by U.S. territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included in this report.

Transportation End-Use Sector. Transportation activities (excluding international bunker fuels) accounted for 33 percent of CO₂ emissions from fossil fuel combustion in 2011.¹³ Virtually all of the energy consumed in this end-use sector came from petroleum products. Nearly 65 percent of the emissions resulted from gasoline consumption for personal vehicle use. The remaining emissions came from other transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft. From 1990 to 2011, transportation emissions rose by 17 percent due, in large part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased 34 percent from 1990 to 2011, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices over much of this period. It is noted that the more recent trend for transportation has shown a general decline in emissions, due to recent slow growth in economic activity, higher fuel prices, and an associated decrease in the demand for passenger transportation.

Industrial End-Use Sector. Industrial CO₂ emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 26 percent of CO₂ from fossil fuel combustion in 2011. Approximately 56 percent of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications. In contrast to the other end-use sectors, emissions from industry have steadily declined since 1990. This decline is 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.

Residential and Commercial End-Use Sectors. The residential and commercial end-use sectors accounted for 21 and 18 percent, respectively, of CO₂ emissions from fossil fuel combustion in 2011. Both sectors relied heavily on electricity for meeting energy demands, with 71 and 77 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking. Emissions from the residential and commercial end-use sectors have increased by 21 percent and 27 percent since 1990, respectively, due to increasing electricity consumption for lighting, heating, air conditioning, and operating appliances.

Electricity Generation. The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators consumed 36 percent of U.S. energy from fossil fuels and emitted 41 percent of the CO₂ from

¹³ If emissions from international bunker fuels are included, the transportation end-use sector accounted for 34.5 percent of U.S. emissions from fossil fuel combustion in 2011.

fossil fuel combustion in 2011. The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low CO₂ emitting energy technologies, particularly non-fossil options such as nuclear, hydroelectric, or geothermal energy. Electricity generators relied on coal for approximately 42 percent their total energy requirements in 2011, and accounted for 95 percent of all coal consumed for energy in the United States in 2011. Recently a decrease in the carbon intensity of fuels consumed to generate electricity has occurred due to a decrease in coal consumption, and increased natural gas consumption and other generation sources. Across the time series, changes in electricity demand and the carbon intensity of fuels used for electricity generation have a significant impact on CO₂ emissions.

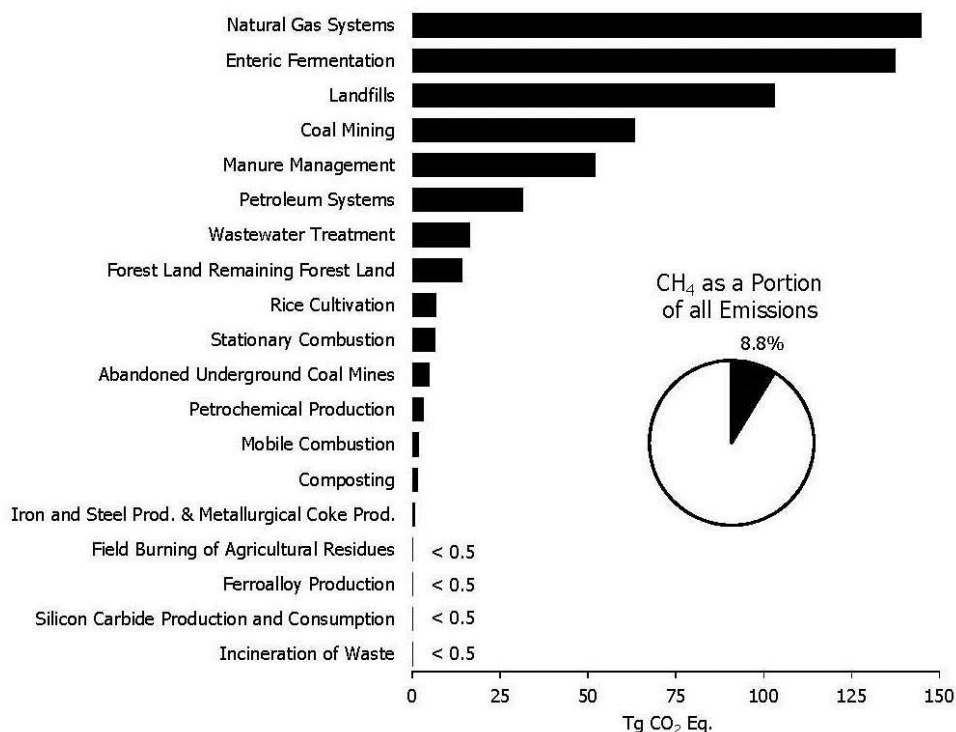
Other significant CO₂ trends included the following:

- CO₂ emissions from non-energy use of fossil fuels have increased by 13.1 Tg CO₂ Eq. (11.2 percent) from 1990 through 2011. Emissions from non-energy uses of fossil fuels were 130.6 Tg CO₂ Eq. in 2011, which constituted 2.3 percent of total national CO₂ emissions, approximately the same proportion as in 1990.
- CO₂ emissions from iron and steel production and metallurgical coke production increased by 8.5 Tg CO₂ Eq. (15.3 percent) from 2010 to 2011, continuing a two-year trend of increasing emissions primarily due to increased steel production associated with improved economic conditions. Despite this, from 1990 through 2011, emissions declined by 35.6 percent (35.5 Tg CO₂ Eq.). This overall decline is due to the restructuring of the industry, technological improvements, and increased scrap utilization.
- In 2011, CO₂ emissions from cement production increased by 0.7 Tg CO₂ Eq. (2.3 percent) from 2010. After decreasing in 1991 by 2.2 percent from 1990 levels, cement production emissions grew every year through 2006. Since 2006, emissions have fluctuated through 2011 due to the economic recession and associated decrease in demand for construction materials. Overall, from 1990 to 2011, emissions from cement production have decreased by 4.9 percent, a decrease of 1.6 Tg CO₂ Eq.
- Net CO₂ uptake from Land Use, Land-Use Change, and Forestry increased by 110.5 Tg CO₂ Eq. (13.9 percent) from 1990 through 2011. This increase was primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in aboveground and belowground tree biomass, and harvested wood pools. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of carbon accumulation in urban trees increased.

Methane Emissions

Methane (CH₄) is more than 20 times as effective as CO₂ at trapping heat in the atmosphere (IPCC 1996). Over the last two hundred and fifty years, the concentration of CH₄ in the atmosphere increased by 158 percent (IPCC 2007). Anthropogenic sources of CH₄ include natural gas and petroleum systems, agricultural activities, landfills, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-8).

Figure ES-8: 2011 Sources of CH₄ Emissions



Some significant trends in U.S. emissions of CH₄ include the following:

- Natural gas systems were the largest anthropogenic source category of CH₄ emissions in the United States in 2011 with 144.7 Tg CO₂ Eq. of CH₄ emitted into the atmosphere. Those emissions have decreased by 16.5 Tg CO₂ Eq. (10.2 percent) since 1990. The decrease in CH₄ emissions is due largely to a decrease in emissions from transmission and storage due to increased voluntary reductions and a decrease in distribution emissions due to a decrease in cast iron and unprotected steel pipelines. Emissions from field production accounted for approximately 37 percent of CH₄ emissions from natural gas systems in 2011. CH₄ emissions from field production decreased by 12 percent from 1990 through 2011; however, the trend was not stable over the time series—emissions from this source increased by 43 percent from 1990 through 2006, and then declined by 38 percent from 2006 to 2011. Reasons for this trend include such factors as increased voluntary reductions, as well as the effects of the recent global economic slowdown.
- Enteric fermentation is the second largest anthropogenic source of CH₄ emissions in the United States. In 2011, enteric fermentation CH₄ emissions were 137.4 Tg CO₂ Eq. (23.4 percent of total CH₄ emissions), which represents an increase of 4.6 Tg CO₂ Eq. (3.5 percent) since 1990. This increase in emissions from 1990 to 2011 in enteric generally follows the increasing trends in cattle populations. From 1990 to 1995 emissions increased and then decreased from 1996 to 2001, mainly due to fluctuations in beef cattle populations and increased digestibility of feed for feedlot cattle. Emissions generally increased from 2002 to 2007, though with a slight decrease in 2004, as both dairy and beef populations underwent increases and the literature for dairy cow diets indicated a trend toward a decrease in feed digestibility for those years. Emissions decreased again from 2008 to 2011 as beef cattle populations again decreased.
- Landfills are the third largest anthropogenic source of CH₄ emissions in the United States, accounting for 17.5 percent of total CH₄ emissions (103.0 Tg CO₂ Eq.) in 2011. From 1990 to 2011, CH₄ emissions from landfills decreased by 44.7 Tg CO₂ Eq. (30.3 percent), with small increases occurring in some interim years. This downward trend in overall emissions can be attributed to a 21 percent reduction in the amount of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in MSW landfills over the time series (EPA 2010) and an increase in the amount of landfill gas collected and

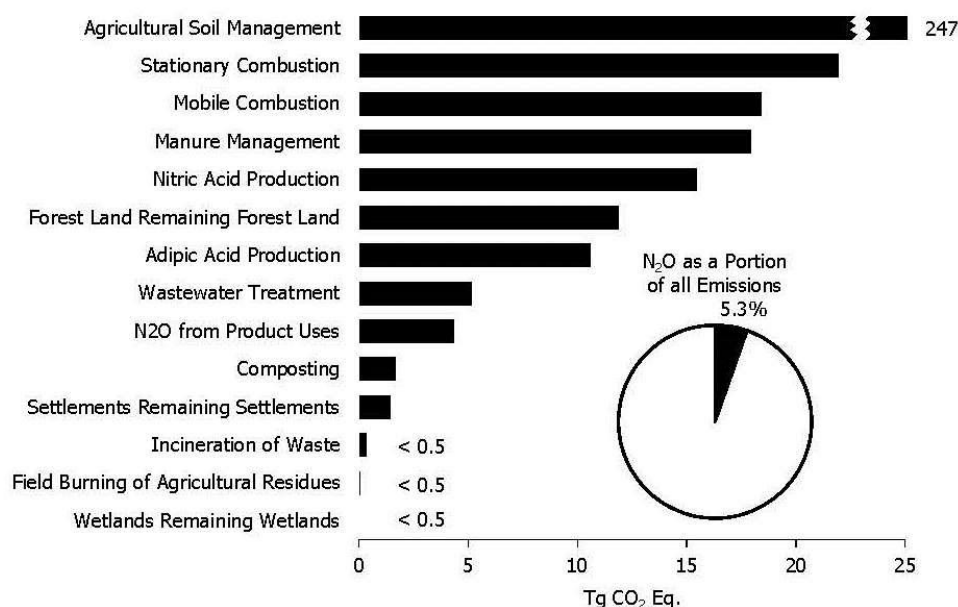
combusted,¹⁴ which has more than offset the additional CH₄ emissions resulting from an increase in the amount of municipal solid waste landfilled.

- In 2011, CH₄ emissions from coal mining were 63.2 Tg CO₂ Eq., a 9.2 Tg CO₂ Eq. (12.6 percent) decrease under 2010 emission levels. The overall decline of 20.8 Tg CO₂ Eq. (24.8 percent) from 1990 results from the mining of less gassy coal from underground mines and the increased use of CH₄ collected from degasification systems.
- Methane emissions from manure management increased by 65.3 percent since 1990, from 31.5 Tg CO₂ Eq. in 1990 to 52.0 Tg CO₂ Eq. in 2011. The majority of this increase was from swine and dairy cow manure, since the general trend in manure management is one of increasing use of liquid systems, which tends to produce greater CH₄ emissions. The increase in liquid systems is the combined result of a shift to larger facilities, and to facilities in the West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the application of manure nutrients have shifted manure management practices at smaller dairies from daily spread to manure managed and stored on site.

Nitrous Oxide Emissions

N₂O 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 N₂O emissions are much lower than CO₂ emissions, N₂O is approximately 300 times more powerful than CO₂ at trapping heat in the atmosphere (IPCC 1996). Since 1750, the global atmospheric concentration of N₂O has risen by approximately 19 percent (IPCC 2007). The main anthropogenic activities producing N₂O in the United States are agricultural soil management, stationary fuel combustion, fuel combustion in motor vehicles, manure management and nitric acid production (see Figure ES-9).

Figure ES-9: 2011 Sources of N₂O Emissions



Some significant trends in U.S. emissions of N₂O include the following:

¹⁴ The CO₂ produced from combusted landfill CH₄ at landfills is not counted in national inventories as it is considered part of the natural C cycle of decomposition.

- Agricultural soils accounted for approximately 69.3 percent of N₂O emissions and 3.7 percent of total emissions in the United States in 2011. Estimated emissions from this source in 2011 were 247.2 Tg CO₂ Eq. Annual N₂O emissions from agricultural soils fluctuated between 1990 and 2011, although overall emissions were 8.5 percent higher in 2011 than in 1990. Annual N₂O emissions from agricultural soils fluctuated between 1990 and 2011, largely as a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.
- N₂O emissions from stationary combustion increased 9.7 Tg CO₂ Eq. (79.3 percent) from 1990 through 2011. N₂O emissions from this source increased primarily as a result of an increase in the number of coal fluidized bed boilers in the electric power sector.
- In 2011, N₂O emissions from mobile combustion were 18.5 Tg CO₂ Eq. (5.2 percent of U.S. N₂O emissions). From 1990 to 2011, N₂O emissions from mobile combustion decreased by 58.0 percent. However, from 1990 to 1998 emissions increased by 25.6 percent, due to control technologies that reduced NO_x emissions while increasing N₂O emissions. Since 1998, newer control technologies have led to an overall decline of 36.8 Tg CO₂ Eq. (66.6 percent) in N₂O from this source.
- N₂O emissions from adipic acid production were 10.6 Tg CO₂ Eq. in 2011, and have decreased significantly in recent years due to the widespread installation of pollution control measures. Emissions from adipic acid production have decreased by 32.9 percent since 1990 and by 39.6 percent since a peak in 1995.

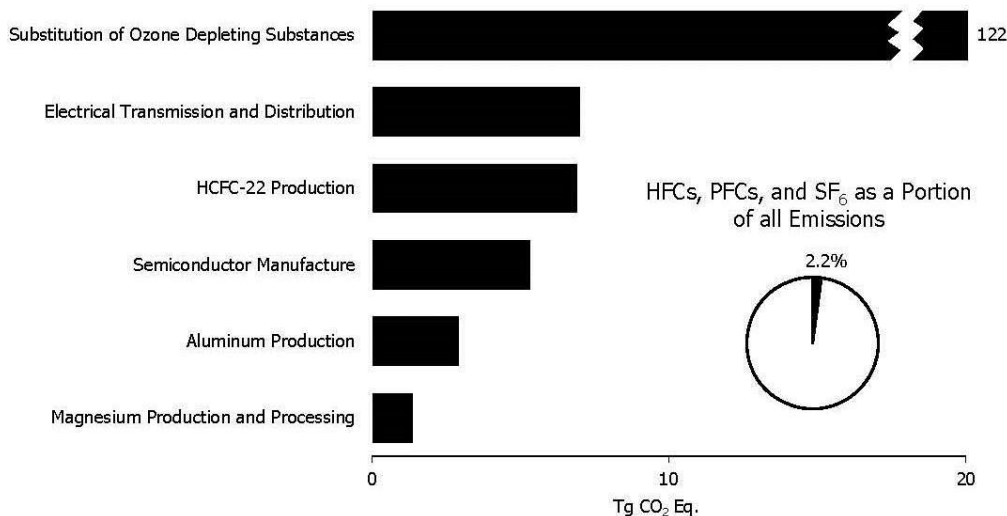
HFC, PFC, and SF₆ Emissions

HFCs and PFCs are families of synthetic chemicals that are used as alternatives to Ozone Depleting Substances, 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 SF₆, are potent greenhouse gases. In addition to having high global warming potentials, SF₆ and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas the IPCC has evaluated (IPCC 1996).

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

Figure ES-10: 2011 Sources of HFCs, PFCs, and SF₆ Emissions



Some significant trends in U.S. HFC, PFC, and SF₆ emissions include the following:

- Emissions resulting from the substitution of ozone depleting substances (ODS) (e.g., CFCs) have been consistently increasing, from small amounts in 1990 to 121.7 Tg CO₂ Eq. in 2011. Emissions from ODS substitutes are both the largest and the fastest growing source of HFC, PFC, and SF₆ emissions. These emissions have been increasing as phase-out of ODS required under the Montreal Protocol came into effect, especially after 1994, when full market penetration was made for the first generation of new technologies featuring ODS substitutes.
- HFC emissions from the production of HCFC-22 decreased by 81.0 percent (29.5 Tg CO₂ Eq.) from 1990 through 2011, 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.
- SF₆ emissions from electric power transmission and distribution systems decreased by 73.6 percent (19.6 Tg CO₂ Eq.) from 1990 to 2011, primarily because of higher purchase prices for SF₆ and efforts by industry to reduce emissions.
- PFC emissions from aluminum production decreased by 84.0 percent (15.5 Tg CO₂ Eq.) from 1990 to 2011, due to both industry emission reduction efforts and declines in domestic aluminum production.

ES.3. 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), Figure ES-11 and Table ES-4 aggregate emissions and sinks by these chapters. Emissions of all gases can be summed from each source category from IPCC guidance. Over the twenty-two-year period of 1990 to 2011, total emissions in the Energy, Industrial Processes, and Agriculture sectors grew by 478.4 Tg CO₂ Eq. (9.1 percent), 10.3 Tg CO₂ Eq. (3.3 percent), and 47.6 Tg CO₂ Eq. (11.5 percent), respectively. Emissions from the Waste and Solvent and Other Product Use sectors decreased by 40.2 Tg CO₂ Eq. (23.9 percent) and less than 0.1 Tg CO₂ Eq. (0.4 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry (LULUCF) sector (magnitude of emissions plus CO₂ flux from all LULUCF source categories) increased by 87.6 Tg CO₂ Eq. (11.2 percent).

Figure ES-11: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

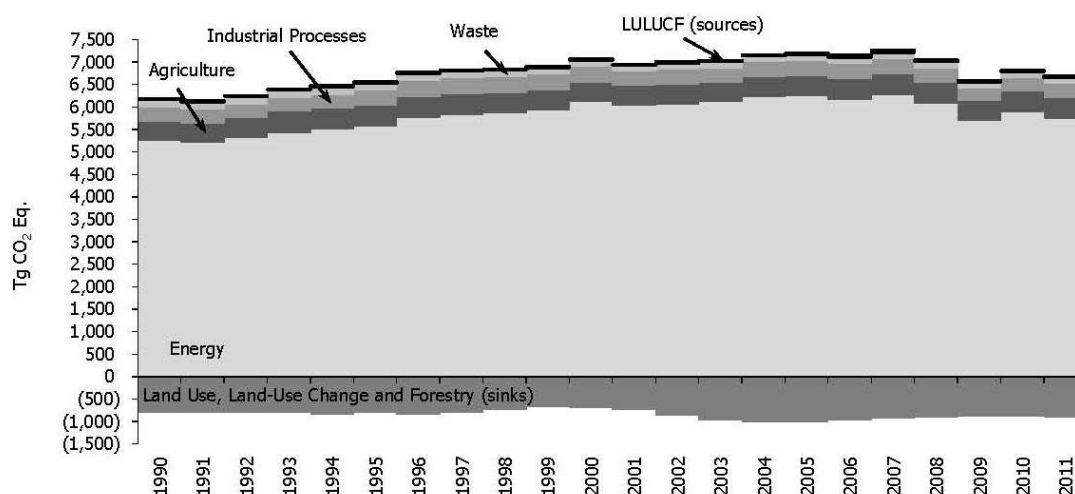


Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg or million metric tons CO₂ Eq.)

Chapter/IPCC Sector	1990	2005	2007	2008	2009	2010	2011
Energy	5,267.3	6,251.6	6,266.9	6,096.2	5,699.2	5,889.1	5,745.7
Industrial Processes	316.1	330.8	347.2	318.7	265.3	303.4	326.5
Solvent and Other Product Use	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Agriculture	413.9	446.2	470.9	463.6	459.2	462.3	461.5
Land-Use Change and Forestry	13.7	25.4	37.3	27.2	20.4	19.7	36.6
Waste	167.8	136.9	136.5	138.6	138.1	131.4	127.7
Total Emissions	6,183.3	7,195.3	7,263.2	7,048.8	6,586.6	6,810.3	6,702.3
Land-Use Change and Forestry (Sinks)	(794.5)	(997.8)	(929.2)	(902.6)	(882.6)	(888.8)	(905.0)
Net Emissions (Emissions and Sinks)	5,388.7	6,197.4	6,334.0	6,146.2	5,704.0	5,921.5	5,797.3

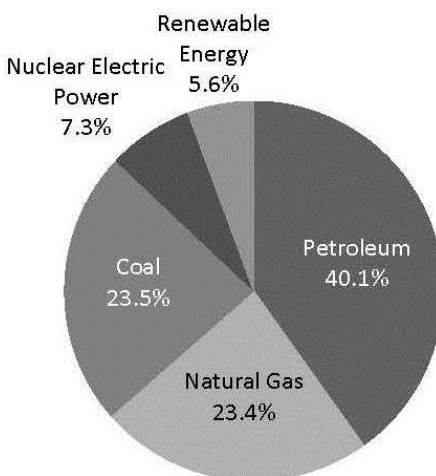
* The net CO₂ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Energy

The Energy chapter 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. CO₂ emissions for the period of 1990 through 2011. In 2011, approximately 87 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 13 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure ES-12). Energy-related activities are also responsible for CH₄ and N₂O emissions (43 percent and 11 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 85.7 percent of total U.S. greenhouse gas emissions in 2011.

Figure ES-12: 2011 U.S. Energy Consumption by Energy Source



Industrial Processes

The Industrial Processes chapter 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 CO₂, CH₄, and N₂O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, lime production, other process uses of carbonates (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, glass production, CO₂ consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF₆. Overall, emission sources in the Industrial Process chapter account for 4.9 percent of U.S. greenhouse gas emissions in 2011.

Solvent and Other Product Use

The Solvent and Other Product Use chapter contains greenhouse gas emissions that are produced as a by-product of various solvent and other product uses. In the United States, emissions from N₂O from product uses, the only source of greenhouse gas emissions from this sector, accounted for about 0.1 percent of total U.S. anthropogenic greenhouse gas emissions on a carbon equivalent basis in 2011.

Agriculture

The Agricultural chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and agricultural CO₂ fluxes, which are addressed in the Land Use, Land-Use Change, and Forestry chapter). 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. CH₄ and N₂O were the primary greenhouse gases emitted by agricultural activities. CH₄ emissions from enteric fermentation and manure management represented 23.4 percent and 8.9 percent of total CH₄ emissions from anthropogenic activities, respectively, in 2011. Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. N₂O emissions in 2011, accounting for 69.3 percent. In 2011, emission sources accounted for in the Agricultural chapters were responsible for 6.9 percent of total U.S. greenhouse gas emissions.

Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry chapter contains emissions of CH₄ and N₂O, and emissions and removals of CO₂ 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 resulted in a net uptake (sequestration) of C in the United States. Forests (including vegetation, soils, and harvested wood) accounted for 92 percent of total 2011 net CO₂ flux, urban trees accounted for 8 percent, mineral and organic soil carbon stock changes accounted for 1 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2011. 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 and organic soils sequester approximately 5 times as much C as is emitted from these soils through liming and urea fertilization. The mineral soil C sequestration is largely due to the conversion of cropland to permanent 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 2011 resulted in a net C sequestration of 905.0 Tg CO₂ Eq. (Table ES-5). This represents an offset of 16.1 percent of total U.S. CO₂ emissions, or 13.5 percent of total greenhouse gas emissions in 2011. Between 1990 and 2011, total land use, land-use change, and forestry net C flux resulted in a 13.9 percent increase in CO₂ sequestration, primarily due to an increase in the rate of net C accumulation in forest C stocks, particularly in aboveground and belowground tree biomass, and harvested wood pools. Annual C accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of annual C accumulation increased in urban trees.

Table ES-5: Net CO₂ Flux from Land Use, Land-Use Change, and Forestry (Tg or million metric tons CO₂ Eq.)

Sink Category	1990	2005	2007	2008	2009	2010	2011
Forest Land Remaining Forest Land	(696.8)	(905.0)	(859.3)	(833.3)	(811.3)	(817.6)	(833.5)
Cropland Remaining Cropland	(34.1)	(20.3)	(6.6)	(5.2)	(4.6)	(3.0)	(2.9)
Land Converted to Cropland	21.0	13.5	14.5	14.5	14.5	14.5	14.5
Grassland Remaining Grassland	(5.3)	(1.0)	7.1	7.2	7.3	7.3	7.4
Land Converted to Grassland	(7.7)	(10.2)	(9.0)	(9.0)	(8.9)	(8.8)	(8.8)
Settlements Remaining Settlements	(47.5)	(63.2)	(65.0)	(66.0)	(66.9)	(67.9)	(68.8)
Other (Landfilled Yard Trimmings and Food Scraps)	(24.2)	(11.6)	(10.9)	(10.9)	(12.7)	(13.3)	(13.0)
Total	(794.5)	(997.8)	(929.2)	(902.6)	(882.6)	(888.8)	(905.0)

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

Emissions from Land Use, Land-Use Change, and Forestry are shown in Table ES-6. Liming of agricultural soils and urea fertilization in 2011 resulted in CO₂ emissions of 8.1 Tg CO₂ Eq. (8,117 Gg). Lands undergoing peat extraction (i.e., *Peatlands Remaining Peatlands*) resulted in CO₂ emissions of 0.9 Tg CO₂ Eq. (918 Gg), and N₂O emissions of less than 0.05 Tg CO₂ Eq. The application of synthetic fertilizers to forest soils in 2011 resulted in direct N₂O emissions of 0.4 Tg CO₂ Eq. (1 Gg). Direct N₂O emissions from fertilizer application to forest soils have increased by 455 percent since 1990, but still account for a relatively small portion of overall emissions. Additionally, direct N₂O emissions from fertilizer application to settlement soils in 2011 accounted for 1.5 Tg CO₂ Eq. (5 Gg). This represents an increase of 51 percent since 1990. Forest fires in 2011 resulted in CH₄ emissions of 14.2 Tg CO₂ Eq. (675 Gg), and in N₂O emissions of 11.6 Tg CO₂ Eq. (37 Gg).

Table ES-6: Emissions from Land Use, Land-Use Change, and Forestry (Tg or million metric tons CO₂ Eq.)

Source Category	1990	2005	2007	2008	2009	2010	2011
CO₂	8.1	8.9	9.2	9.6	8.3	9.4	9.0
Cropland Remaining Cropland: Liming of Agricultural	4.7	4.3	4.5	5.0	3.7	4.7	4.5

Soils							
Cropland Remaining Cropland: Urea Fertilization	2.4	3.5	3.8	3.6	3.6	3.7	5.3
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	1.0	1.1	1.0	1.0	1.1	1.0	0.9
CH ₄	2.5	8.0	14.4	8.7	5.7	4.7	14.2
Forest Land Remaining Forest Land: Forest Fires	2.5	8.0	14.4	8.7	5.7	4.7	14.2
N ₂ O	3.1	8.4	13.7	8.9	6.4	5.6	13.4
Forest Land Remaining Forest Land: Forest Fires	2.0	6.6	11.7	7.1	4.7	3.8	11.6
Forest Land Remaining Forest Land: Forest Soils	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Settlements Remaining Settlements: Settlement Soils	1.0	1.5	1.6	1.5	1.4	1.5	1.5
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
Total	13.7	25.4	37.3	27.2	20.4	19.7	36.6

+ Less than 0.05 Tg CO₂ Eq.

Note: Totals may not sum due to independent rounding.

Waste

The Waste chapter contains emissions from waste management activities (except incineration of waste, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic greenhouse gas emissions in the Waste chapter, accounting for 80.7 percent of this chapter's emissions, and 17.5 percent of total U.S. CH₄ emissions.¹⁵ Additionally, wastewater treatment accounts for 16.7 percent of Waste emissions, 2.8 percent of U.S. CH₄ emissions, and 1.5 percent of U.S. N₂O emissions. Emissions of CH₄ and N₂O from composting are also accounted for in this chapter, generating emissions of 1.5 Tg CO₂ Eq. and 1.7 Tg CO₂ Eq., respectively. Overall, emission sources accounted for in the Waste chapter generated 1.9 percent of total U.S. greenhouse gas emissions in 2011.

ES.4. Other Information

Emissions by Economic Sector

Throughout the Inventory of U.S. Greenhouse Gas Emissions and Sinks report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes; Solvent Use; Agriculture; Land Use, 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, Agriculture, and U.S. Territories.

Table ES-7 summarizes emissions from each of these sectors, and Figure ES-13 shows the trend in emissions by sector from 1990 to 2011.

¹⁵ Landfills also store carbon, due to 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 Inventory report.

Figure ES-13: Emissions Allocated to Economic Sectors

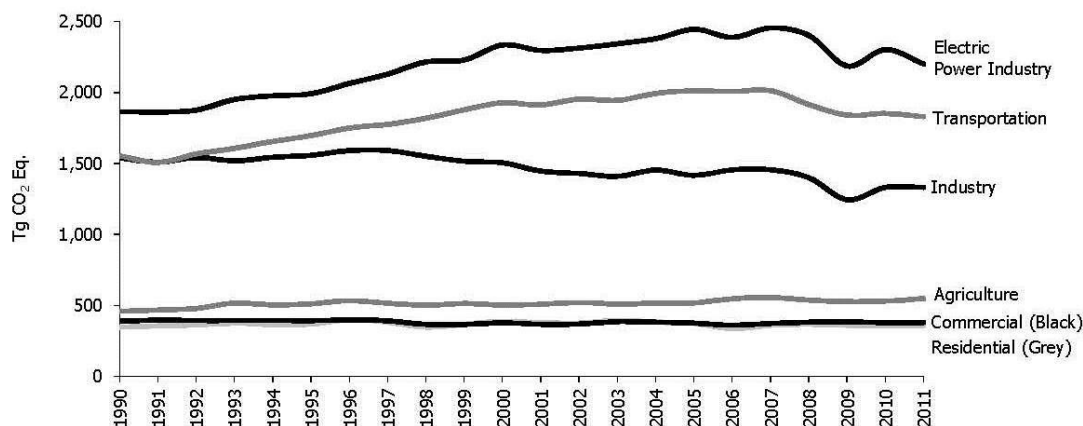


Table ES-7: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg or million metric tons CO₂ Eq.)

Implied Sectors	1990	2005	2007	2008	2009	2010	2011
Electric Power Industry	1,866.1	2,445.7	2,455.6	2,402.0	2,187.6	2,303.0	2,200.9
Transportation	1,553.2	2,012.3	2,013.1	1,916.0	1,840.6	1,852.2	1,829.4
Industry	1,538.8	1,416.2	1,456.1	1,398.8	1,244.2	1,331.8	1,332.0
Agriculture	458.0	517.4	555.6	535.3	525.4	528.7	546.6
Commercial	388.1	374.1	372.0	380.9	382.9	376.9	378.0
Residential	345.4	371.3	358.2	366.0	358.1	359.6	357.3
U.S. Territories	33.7	58.2	52.6	49.8	47.9	58.0	58.0
Total Emissions	6,183.3	7,195.3	7,263.2	7,048.8	6,586.6	6,810.3	6,702.3
Land Use, Land-Use Change, and Forestry (Sinks)	(794.5)	(997.8)	(929.2)	(902.6)	(882.6)	(888.8)	(905.0)
Net Emissions (Sources and Sinks)	5,388.7	6,197.4	6,334.0	6,146.2	5,704.0	5,921.5	5,797.3

Note: Totals may not sum due to independent rounding. Emissions include CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆. See Table 2-12 for more detailed data.

Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2011. Transportation activities, in aggregate, accounted for the second largest portion (27 percent), while emissions from industry accounted for the third largest portion (20 percent) of U.S. greenhouse gas emissions in 2011. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. 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 energy efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by, in order of importance, the agriculture, commercial, and residential sectors, plus emissions from U.S. Territories. Activities related to agriculture accounted for 8 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N₂O emissions from agricultural soil management and CH₄ emissions from enteric fermentation. The commercial and residential sectors accounted for 6 and 5 percent, respectively, of emissions and U.S. Territories accounted for 1 percent of emissions; emissions from these sectors primarily consisted of CO₂ emissions from fossil fuel combustion. CO₂ 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 ES-8 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.¹⁶ These source categories include CO₂ from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO₂ and N₂O from incineration of waste, CH₄ and N₂O from stationary sources, and SF₆ from electrical transmission and distribution systems.

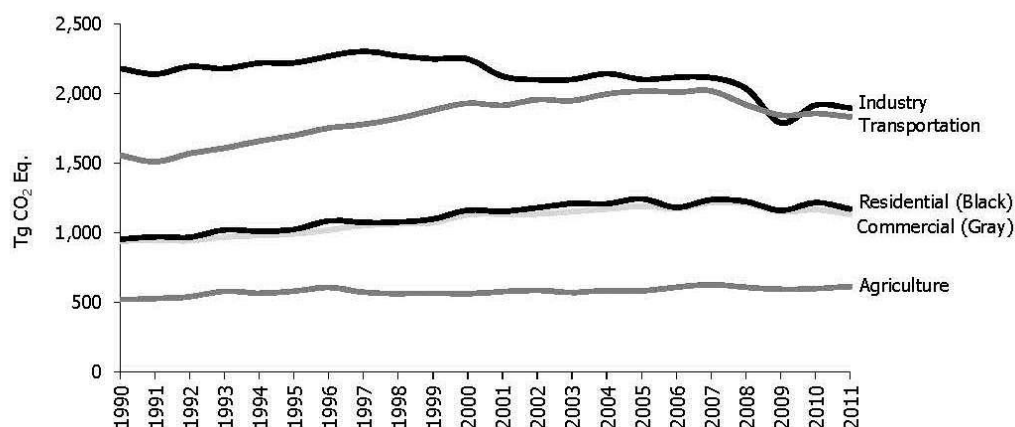
When emissions from electricity are distributed among these sectors, industrial activities account for the largest share of U.S. greenhouse gas emissions (28 percent) in 2011. Transportation is the second largest contributor to total U.S. emissions (27 percent). The residential and commercial sectors contributed the next largest shares of total U.S. greenhouse gas emissions in 2011. Emissions from these sectors increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (e.g., lighting, appliances, etc.). In all sectors except agriculture, CO₂ accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels. Figure ES-14 shows the trend in these emissions by sector from 1990 to 2011.

Table ES-8: U.S Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (Tg or million metric tons CO₂ Eq.)

Implied Sectors	1990	2005	2007	2008	2009	2010	2011
Industry	2,181.3	2,102.4	2,113.6	2,036.3	1,789.8	1,916.9	1,897.2
Transportation	1,556.3	2,017.2	2,018.2	1,920.8	1,845.2	1,856.9	1,833.7
Residential	939.5	1,192.4	1,215.6	1,211.1	1,150.8	1,165.2	1,131.0
Commercial	953.1	1,243.6	1,237.1	1,223.6	1,159.6	1,216.3	1,169.8
Agriculture	519.3	581.5	626.2	607.1	593.3	597.1	612.6
U.S. Territories	33.7	58.2	52.6	49.8	47.9	58.0	58.0
Total Emissions	6,183.3	7,195.3	7,263.2	7,048.8	6,586.6	6,810.3	6,702.3
Land Use, Land-Use Change, and Forestry (Sinks)	(794.5)	(997.8)	(929.2)	(902.6)	(882.6)	(888.8)	(905.0)
Net Emissions (Sources and Sinks)	5,388.7	6,197.4	6,334.0	6,146.2	5,704.0	5,921.5	5,797.3

See Table 2-14 for more detailed data.

Figure ES-14: Emissions with Electricity Distributed to Economic Sectors



¹⁶ 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.

Box ES 2: 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 2011; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

Table ES-9 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.4 percent since 1990. This rate is slightly faster than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product and national population (see Figure ES-15).

Table ES-9: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	2005	2007	2008	2009	2010	2011	Growth Rate ^a
GDP ^b	100	157	165	164	159	163	166	2.5%
Electricity Consumption ^c	100	134	137	136	131	137	136	1.5%
Fossil Fuel Consumption ^c	100	119	119	116	109	112	101	0.1%
Energy Consumption ^c	100	119	120	117	111	115	102	0.1%
Population ^d	100	118	121	122	123	124	125	1.1%
Greenhouse Gas Emissions ^e	100	116	117	114	107	110	108	0.4%

^a Average annual growth rate

^b Gross Domestic Product in chained 2005 dollars (BEA 2012)

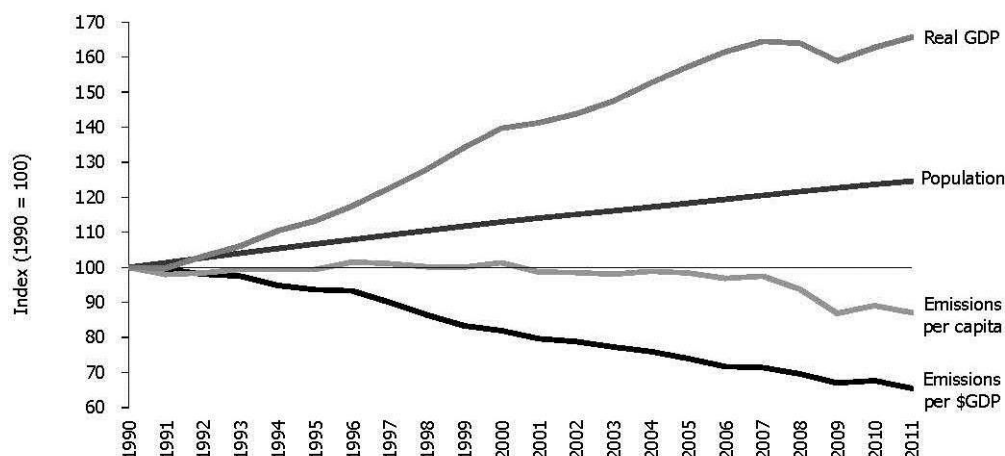
^c Energy content-weighted values (EIA 2013)

^d U.S. Census Bureau (2012)

^e GWP-weighted values

Figure ES-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product

Source: BEA (2012), U.S. Census Bureau (2012), and emission estimates in this report.



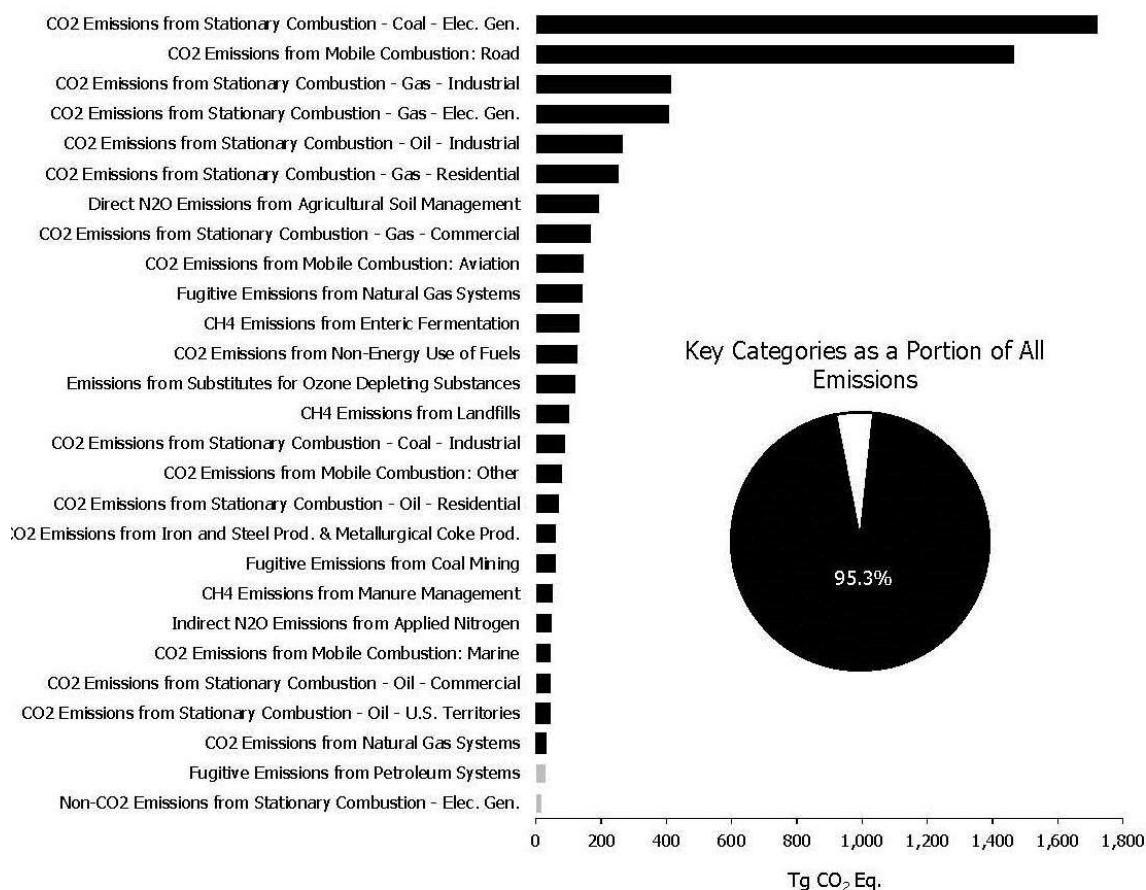
Key Categories

The IPCC *Good Practice Guidance* (IPCC 2000) defines a key category as a “[source or sink category] that is prioritized within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.”¹⁷ By definition, key categories are sources or sinks that have the greatest contribution to the absolute overall level of national emissions in any of the years covered by the time series. In addition, when an entire time series of emission estimates is prepared, a thorough investigation of key categories must also account for the influence of trends of individual source and sink categories. Finally, a qualitative evaluation of key categories should be performed, in order to capture any key categories that were not identified in either of the quantitative analyses.

Figure ES-16 presents 2011 emission estimates for the key categories as defined by a level analysis (i.e., the contribution of each source or sink category to the total inventory level). The UNFCCC reporting guidelines request that key category analyses be reported at an appropriate level of disaggregation, which may lead to source and sink category names which differ from those used elsewhere in the inventory report. For more information regarding key categories, see section 1.5 and Annex 1.

¹⁷ See Chapter 7 “Methodological Choice and Recalculation” in IPCC (2000). <<http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm>>

Figure ES-16: 2011 Key Categories



Note: For a complete discussion of the key category analysis, see Annex 1. Black bars indicate a Tier 1 level assessment key category. Gray bars indicate a Tier 2 level assessment key category.

Quality Assurance and Quality Control (QA/QC)

The United States seeks to continually improve the quality, transparency, and credibility of the Inventory of U.S. Greenhouse Gas Emissions and Sinks. To assist in these efforts, the United States implemented a systematic approach to QA/QC. While QA/QC has always been an integral part of the U.S. national system for inventory development, the procedures followed for the current inventory have been formalized in accordance with the QA/QC plan and the UNFCCC reporting guidelines.

Uncertainty Analysis of Emission Estimates

While the current U.S. emissions inventory provides a solid foundation for the development of a more detailed and comprehensive national inventory, there are uncertainties associated with the emission estimates. Some of the current estimates, such as those for CO₂ emissions from energy-related activities and cement processing, are considered to have low uncertainties. For some other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated increases the uncertainty associated with the estimates presented. Acquiring a better understanding of the uncertainty associated with inventory estimates is an important step in helping to prioritize future work and improve the overall quality of the Inventory. Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the IPCC

Good Practice Guidance (IPCC 2000) and require that countries provide single estimates of uncertainty for source and sink categories.

Currently, a qualitative discussion of uncertainty is presented for all source and sink categories. Within the discussion of each emission source, specific factors affecting the uncertainty surrounding the estimates are discussed. Most sources also contain a quantitative uncertainty assessment, in accordance with UNFCCC reporting guidelines.

Box ES 3: 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 2006 IPCC Guidelines (IPCC 2006), which states, “Both methodological changes and refinements over time are an essential part of improving inventory quality. It is good practice to change or refine methods” when: available data have changed; the previously used method is not consistent with the IPCC guidelines for that category; a category has become key; the previously used method is insufficient to reflect mitigation activities in a transparent manner; the capacity for inventory preparation has increased; new inventory methods become available; and for correction of errors.” 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 2011) has been recalculated to reflect the change, per the 2006 IPCC Guidelines (IPCC 2006). 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.
