

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 2015. 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 *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The structure of this report is consistent with the UNFCCC guidelines for inventory reporting.⁴

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 gross emissions total presented in this report for the United States excludes emissions and sinks from land use, land-use change, and forestry (LULUCF). The net emissions total presented in this report for the United States includes emissions and sinks from LULUCF. All emissions and sinks are calculated using methods

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 2006).

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/2013/cop19/eng/10a03.pdf>>.

that are consistent with internationally-accepted guidelines 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. The report itself follows this standardized format, and provides an explanation of the methods used to calculate emissions and sinks, and the manner in which those calculations are conducted.

Box ES-2: EPA's Greenhouse Gas Reporting Program

On October 30, 2009, the U.S. Environmental Protection Agency (EPA) published a rule for the mandatory reporting of greenhouse gases from large greenhouse gas 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 carbon dioxide (CO₂) underground for sequestration or other reasons.⁷ 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.

The GHGRP dataset continues to be an important resource for the Inventory, providing not only annual emissions information, but also other annual information, such as activity data and emission factors that can improve and refine national emission estimates and trends over time. GHGRP data also allow EPA to disaggregate national inventory estimates in new ways that can highlight differences across regions and sub-categories of emissions, along with enhancing application of QA/QC procedures and assessment of uncertainties.

EPA uses annual GHGRP data in a number of category estimates and continues to analyze the data on an annual basis, as applicable, for further use to improve the national estimates presented in this Inventory consistent with IPCC guidance.⁸

ES.1 Background Information

Greenhouse gases absorb infrared radiation, thereby trapping heat and making the planet warmer. The most important greenhouse gases directly emitted by humans include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and several other fluorine-containing halogenated substances. Although 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 2015, concentrations of these greenhouse gases have increased globally by 44, 162, and 21 percent, respectively (IPCC 2013 and NOAA/ESRL 2017). 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 climate change 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

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

⁶ See <<http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>>.

⁷ See <<http://www.epa.gov/ghgreporting>> and <<http://ghgdata.epa.gov/ghgp/main.do>>.

⁸ See <http://www.ipcc-nggip.iges.or.jp/public/tb/TFI_Technical_Bulletin_1.pdf>

affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or albedo).⁹ 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 accumulated radiative forcing within a specific time horizon caused by emitting 1 kilogram of the gas, relative to that of the reference gas CO₂ (IPCC 2014). The reference gas used is CO₂, and therefore GWP-weighted emissions are measured in million metric tons of CO₂ equivalent (MMT CO₂ Eq.).^{10,11} All gases in this Executive Summary are presented in units of MMT CO₂ Eq. Emissions by gas in unweighted mass tons are provided in the Trends chapter of this report.

UNFCCC reporting guidelines for national inventories require the use of GWP values from the *IPCC Fourth Assessment Report (AR4)* (IPCC 2007).¹² All estimates are provided throughout the report in both CO₂ equivalents and unweighted units. A comparison of emission values using the AR4 GWP values versus the SAR (IPCC 1996), and the *IPCC Fifth Assessment Report (AR5)* (IPCC 2013) GWP values 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 ^a	25
N ₂ O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
CF ₄	7,390
C ₂ F ₆	12,200
C ₄ F ₁₀	8,860
C ₆ F ₁₄	9,300
SF ₆	22,800
NF ₃	17,200

^a 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 production of CO₂ is not included.
Source: IPCC (2007)

⁹ 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.

¹⁰ Carbon comprises 12/44 of carbon dioxide by weight.

¹¹ One million metric ton is equal to 10¹² grams or one teragram.

¹² See <<http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>>.

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

In 2015, total gross U.S. greenhouse gas emissions were 6,586.7 million metric tons (MMT) of CO₂ Eq. Total U.S. emissions have increased by 3.5 percent from 1990 to 2015, and emissions decreased from 2014 to 2015 by 2.3 percent (153.0 MMT CO₂ Eq.). The decrease in total greenhouse gas emissions between 2014 and 2015 was driven in large part by a decrease in CO₂ emissions from fossil fuel combustion. The decrease in CO₂ emissions from fossil fuel combustion was a result of multiple factors, including: (1) substitution from coal to natural gas consumption in the electric power sector; (2) warmer winter conditions in 2015 resulting in a decreased demand for heating fuel in the residential and commercial sectors; and (3) a slight decrease in electricity demand. Relative to 1990, the baseline for this Inventory, gross emissions in 2015 are higher by 3.5 percent, down from a high of 15.5 percent above 1990 levels in 2007. 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. Overall, net emissions in 2015 were 11.5 percent below 2005 levels as shown in Table ES-2.

Table ES-2 provides a detailed summary of gross U.S. greenhouse gas emissions and sinks for 1990 through 2015.

Figure ES-1: Gross U.S. Greenhouse Gas Emissions by Gas (MMT CO₂ Eq.)

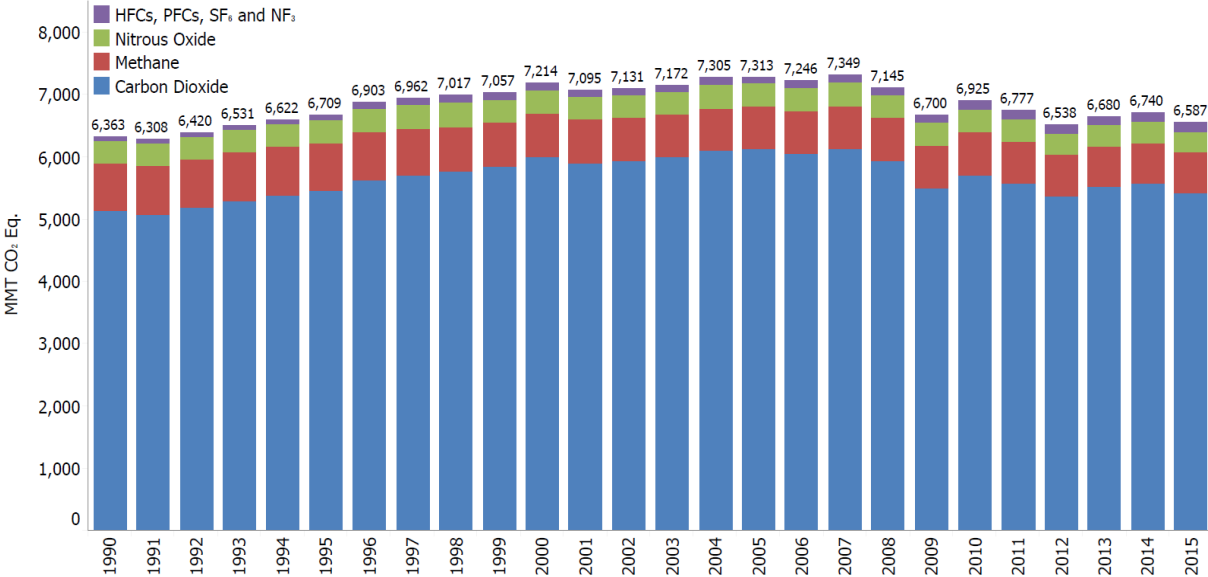


Figure ES-2: Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year

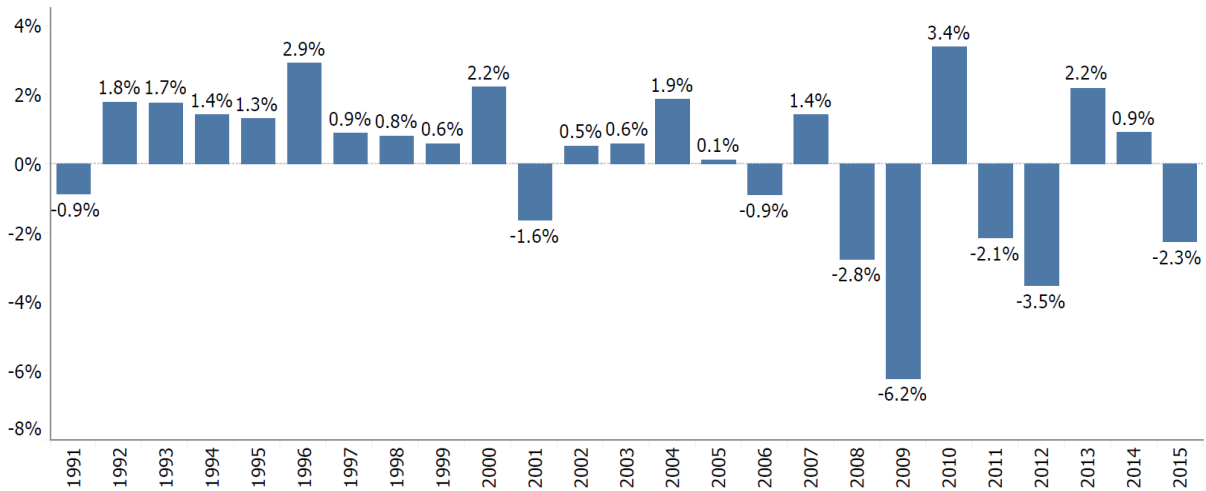


Figure ES-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO₂ Eq.)

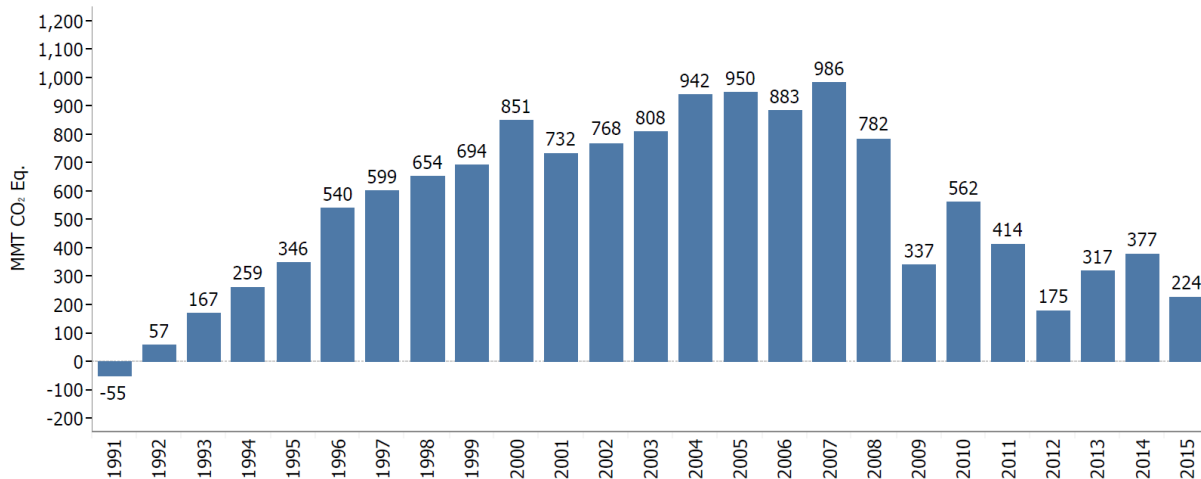


Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO₂ Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO₂	5,123.0	6,131.8	5,569.5	5,362.1	5,514.0	5,565.5	5,411.4
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
<i>Electricity Generation</i>	1,820.8	2,400.9	2,157.7	2,022.2	2,038.1	2,038.0	1,900.7
<i>Transportation^a</i>	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4
<i>Industrial^a</i>	842.5	828.0	775.0	782.9	812.2	806.1	805.5
<i>Residential</i>	338.3	357.8	325.5	282.5	329.7	345.4	319.6
<i>Commercial^a</i>	217.4	223.5	220.4	196.7	221.0	228.7	246.2

<i>U.S. Territories</i>	27.6	49.7	40.9	43.5	42.5	41.4	41.4
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.0	61.1	55.4	53.3	58.6	48.9
Natural Gas Systems	37.7	30.1	35.7	35.2	38.5	42.4	42.4
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.3	27.0	26.3	26.5	26.4	26.5	28.1
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Incineration of Waste	8.0	12.5	10.6	10.4	10.4	10.6	10.7
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
Petroleum Systems	3.6	3.9	4.2	3.9	3.7	3.6	3.6
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Aluminum Production	6.8	4.1	3.3	3.4	3.3	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+	+	+	+	+	+	+
<i>Wood Biomass, Ethanol, and Biodiesel Consumption^b</i>	219.4	230.7	276.4	276.2	299.8	307.1	291.7
<i>International Bunker Fuels^c</i>	103.5	113.1	111.7	105.8	99.8	103.2	110.8
CH₄	780.8	680.9	672.1	666.1	658.8	659.1	655.7
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Natural Gas Systems	194.1	159.7	154.5	156.2	159.2	162.5	162.4
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Manure Management	37.2	56.3	63.0	65.6	63.3	62.9	66.3
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Petroleum Systems	55.5	46.0	48.0	46.4	44.5	43.0	39.9
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Stationary Combustion	8.5	7.4	7.1	6.6	8.0	8.1	7.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Composting	0.4	1.9	1.9	1.9	2.0	2.1	2.1
Mobile Combustion ^a	5.6	2.8	2.3	2.2	2.1	2.1	2.0
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Petrochemical Production	0.2	0.1	+	0.1	0.1	0.1	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+

Incineration of Waste	+	+	+	+	+	+	+
<i>International Bunker Fuels^c</i>	0.2	0.1	0.1	0.1	0.1	0.1	0.1
N₂O	359.5	361.6	364.0	340.7	335.5	335.5	334.8
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Stationary Combustion	11.9	20.2	21.3	21.4	22.9	23.4	23.1
Manure Management	14.0	16.5	17.4	17.5	17.5	17.5	17.7
Mobile Combustion ^a	41.2	35.7	22.8	20.4	18.5	16.6	15.1
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Wastewater Treatment	3.4	4.4	4.8	4.8	4.9	4.9	5.0
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N ₂ O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	1.7	1.7	1.8	1.9	1.9
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
Semiconductor Manufacture	+	0.1	0.2	0.2	0.2	0.2	0.2
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<i>International Bunker Fuels^c</i>	0.9	1.0	1.0	0.9	0.9	0.9	0.9
HFCs	46.6	120.0	154.3	155.9	159.0	166.7	173.2
Substitution of Ozone Depleting Substances ^d	0.3	99.7	145.3	150.2	154.6	161.3	168.5
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	+	0.1	0.1	0.1
PFCs	24.3	6.7	6.9	6.0	5.8	5.8	5.2
Semiconductor Manufacture	2.8	3.2	3.4	3.0	2.8	3.2	3.2
Aluminum Production	21.5	3.4	3.5	2.9	3.0	2.5	2.0
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF₆	28.8	11.7	9.2	6.8	6.4	6.6	5.8
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Magnesium Production and Processing	5.2	2.7	2.8	1.6	1.5	1.0	0.9
Semiconductor Manufacture	0.5	0.7	0.4	0.4	0.4	0.7	0.7
NF₃	+	0.5	0.7	0.6	0.6	0.5	0.6
Semiconductor Manufacture	+	0.5	0.7	0.6	0.6	0.5	0.6
Total Emissions	6,363.1	7,313.3	6,776.7	6,538.3	6,680.1	6,739.7	6,586.7
LULUCF Emissions^e	10.6	23.0	19.9	26.1	19.2	19.7	19.7
LULUCF Carbon Stock Change^f	(830.2)	(754.0)	(769.1)	(779.8)	(782.2)	(781.1)	(778.7)
LULUCF Sector Net Total^g	(819.6)	(731.0)	(749.2)	(753.8)	(763.0)	(761.4)	(758.9)
Net Emissions (Sources and Sinks)	5,543.5	6,582.3	6,027.6	5,784.5	5,917.1	5,978.3	5,827.7

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

+ Does not exceed 0.05 MMT CO₂ Eq.

^a There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

^b Emissions from Wood Biomass and Biofuel 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.

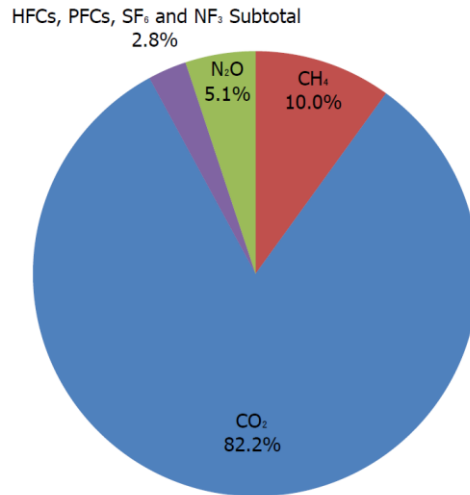
^e LULUCF emissions include the CH₄ and N₂O emissions reported for *Peatlands Remaining Peatlands*, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH₄ emissions from *Land Converted to Coastal Wetlands*; and N₂O emissions from Forest Soils and Settlement Soils.

^f LULUCF Carbon Stock Change is the net C stock change from the following categories: *Forest Land Remaining Forest Land*, *Land Converted to Forest Land*, *Cropland Remaining Cropland*, *Land Converted to Cropland*, *Grassland Remaining Grassland*, *Land Converted to Grassland*, *Wetlands Remaining Wetlands*, *Land Converted to Wetlands*, *Settlements Remaining Settlements*, and *Land Converted to Settlements*. Refer to Table ES-5 for a breakout of emissions and removals for Land Use, Land-Use Change, and Forestry by gas and source category.

^g The LULUCF Sector Net Total is the net sum of all CH₄ and N₂O emissions to the atmosphere plus net carbon stock changes. Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure ES-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2015, weighted by global warming potential. Note, unless otherwise stated, all tables and figures provide total emissions without LULUCF. The primary greenhouse gas emitted by human activities in the United States was CO₂, representing approximately 82.2 percent of total greenhouse gas emissions. The largest source of CO₂, and of overall greenhouse gas emissions, was fossil fuel combustion. Methane emissions, which have decreased by 16.0 percent since 1990, resulted primarily from enteric fermentation associated with domestic livestock, natural gas systems, and decomposition of wastes in landfills. Agricultural soil management, manure 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 hydrofluorocarbon (HFC) emissions. Perfluorocarbon (PFC) emissions resulted as a byproduct of primary aluminum production and from semiconductor manufacturing, electrical transmission and distribution systems accounted for most sulfur hexafluoride (SF₆) emissions, and semiconductor manufacturing is the only source of nitrogen trifluoride (NF₃) emissions.

Figure ES-4: 2015 U.S. Greenhouse Gas Emissions by Gas (Percentages based on MMT CO₂ Eq.)



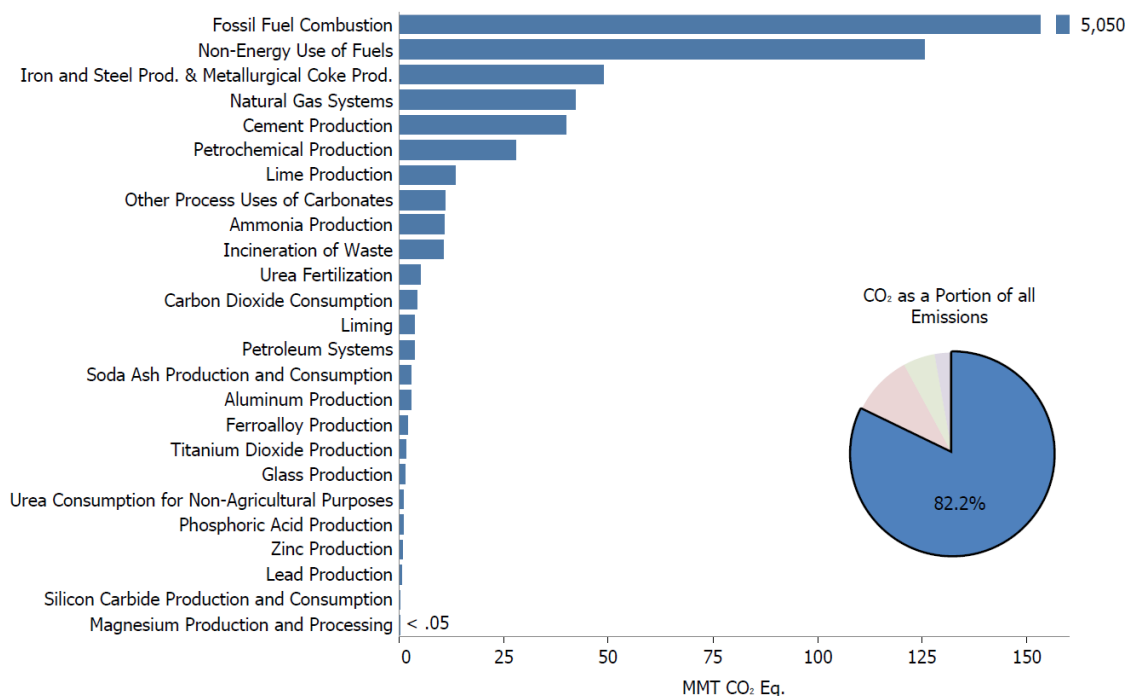
Overall, from 1990 to 2015, total emissions of CO₂ increased by 288.4 MMT CO₂ Eq. (5.6 percent), while total emissions of CH₄ decreased by 125.1 MMT CO₂ Eq. (16.0 percent), and N₂O emissions decreased by 24.7 MMT CO₂ Eq. (6.9 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, SF₆ and NF₃ rose by 85.0 MMT CO₂ Eq. (85.3 percent). From 1990 to 2015, HFCs increased by 126.6 MMT CO₂ Eq. (271.8 percent), PFCs decreased by 19.1 MMT CO₂ Eq. (78.6 percent), SF₆ decreased by 23.0 MMT CO₂ Eq. (79.8 percent), and NF₃ increased by 0.5 MMT CO₂ Eq. (1,057.0 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, SF₆ and NF₃ 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 (C) sequestration in forests, trees in urban areas, agricultural soils, landfilled yard trimmings and food scraps, and coastal wetlands, which, in aggregate, offset

11.8 percent of total emissions in 2015. 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.¹³ Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO₂ have risen approximately 44 percent (IPCC 2013 and NOAA/ESRL 2017), principally due to the combustion of fossil fuels. Within the United States, fossil fuel combustion accounted for 93.3 percent of CO₂ emissions in 2015. Globally, approximately 33,733 MMT of CO₂ were added to the atmosphere through the combustion of fossil fuels in 2014, of which the United States accounted for approximately 16 percent.¹⁴ Changes in land use and forestry practices can lead to net CO₂ emissions (e.g., through conversion of forest land to agricultural or urban use) or to a net sink for CO₂ (e.g., through net additions to forest biomass). Fossil fuel combustion is the greatest source of CO₂ emissions. There are 24 additional sources included in the Inventory (Figure ES-5).

Figure ES-5: 2015 Sources of CO₂ Emissions (MMT CO₂ Eq.)



Note: Fossil Fuel Combustion includes electricity generation, which also includes emissions of less than 0.05 MMT 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 77 percent of GWP-weighted emissions since 1990. The fundamental factors influencing emissions levels include (1) changes in demand for energy and (2) a general decline in the carbon intensity of fuels combusted for energy in recent years by most sectors of the economy. Between 1990 and 2015, CO₂ emissions from fossil fuel

¹³ The term “flux” is used to describe the net emissions of greenhouse gases accounting for both the emissions of CO₂ to and the removals of CO₂ from the atmosphere. Removal of CO₂ from the atmosphere is also referred to as “carbon sequestration.”

¹⁴ Global CO₂ emissions from fossil fuel combustion were taken from International Energy Agency *CO₂ Emissions from Fossil Fuels Combustion – Highlights* IEA (2016). See <<https://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2016.html>>.

combustion increased from 4,740.3 MMT CO₂ Eq. to 5,049.8 MMT CO₂ Eq., a 6.5 percent total increase over the twenty-six-year period. In addition, CO₂ emissions from fossil fuel combustion decreased by 697.2 MMT CO₂ Eq. from 2005 levels, a decrease of approximately 12.1 percent between 2005 and 2015. From 2014 to 2015, these emissions decreased by 152.5 MMT CO₂ Eq. (2.9 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. Long-term factors include population and economic trends, technological changes, shifting energy fuel choices, and various policies at the national, state, and local level. In the short term, the overall consumption and mix of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, overall energy prices, the relative price of different fuels, weather, and the availability of non-fossil alternatives.

Figure ES-6: 2015 CO₂ Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO₂ Eq.)

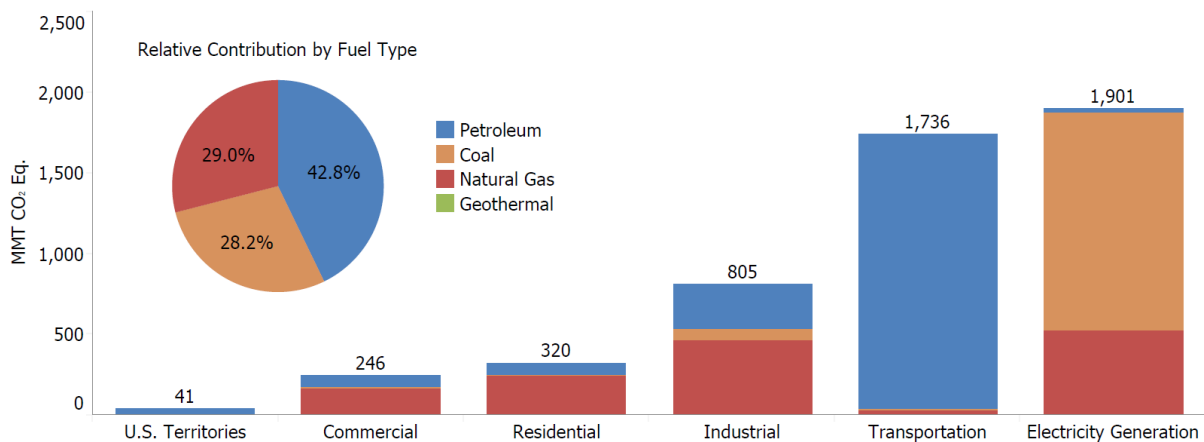
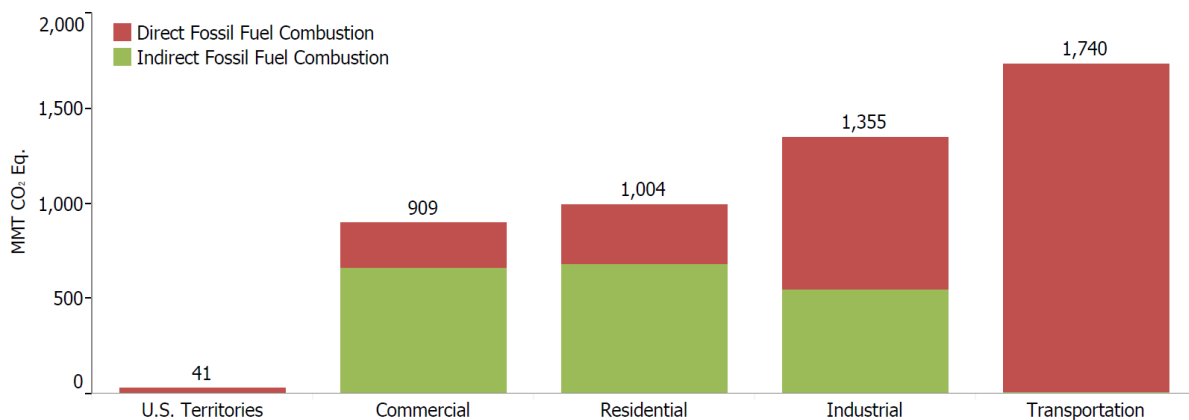


Figure ES-7: 2015 End-Use Sector Emissions of CO₂ from Fossil Fuel Combustion (MMT CO₂ Eq.)



The five major fuel consuming economic sectors contributing to CO₂ emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. Carbon dioxide 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 End-Use Sector (MMT CO₂ Eq.)

End-Use Sector	1990	2005	2011	2012	2013	2014	2015
Transportation^a	1,496.8	1,891.8	1,711.9	1,700.6	1,717.0	1,746.9	1,740.1
Combustion	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4
Electricity	3.0	4.7	4.3	3.9	4.0	4.1	3.7
Industrial^a	1,529.2	1,564.6	1,399.6	1,375.7	1,407.0	1,399.3	1,355.0
Combustion	842.5	828.0	775.0	782.9	812.2	806.1	805.5
Electricity	686.7	736.6	624.7	592.8	594.7	593.2	549.6
Residential	931.4	1,214.1	1,116.2	1,007.8	1,064.6	1,080.1	1,003.9
Combustion	338.3	357.8	325.5	282.5	329.7	345.4	319.6
Electricity	593.0	856.3	790.7	725.3	734.9	734.7	684.3
Commercial^a	755.4	1,026.8	958.4	897.0	925.5	934.7	909.4
Combustion	217.4	223.5	220.4	196.7	221.0	228.7	246.2
Electricity	538.0	803.3	738.0	700.3	704.5	706.0	663.1
U.S. Territories^b	27.6	49.7	40.9	43.5	42.5	41.4	41.4
Total	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Electricity Generation	1,820.8	2,400.9	2,157.7	2,022.2	2,038.1	2,038.0	1,900.7

^a There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

^b 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.

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

Transportation End-Use Sector. When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 34.5 percent of U.S. CO₂ emissions from fossil fuel combustion in 2015. The largest sources of transportation CO₂ emissions in 2015 were passenger cars (42.3 percent), medium- and heavy-duty trucks (23.6 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (17.1 percent), commercial aircraft (6.8 percent), rail (2.5 percent), other aircraft (2.3 percent), pipelines (2.2 percent), and ships and boats (1.9 percent). Annex 3.2 presents the total emissions from all transportation and mobile sources, including CO₂, CH₄, N₂O, and HFCs.

In terms of the overall trend, from 1990 to 2015, total transportation CO₂ emissions increased due, in large part, to increased demand for travel. The number of VMT by light-duty motor vehicles (i.e., passenger cars and light-duty trucks) increased 40 percent from 1990 to 2015,¹⁵ as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices during the beginning of this period. Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to

¹⁵ VMT estimates are based on data from FHWA Highway Statistics Table VM-1 (FHWA 1996 through 2016). In 2011, FHWA changed its methods for estimating VMT by vehicle class, which led to a shift in VMT and emissions among on-road vehicle classes in the 2007 to 2015 time period. In absence of these method changes, light-duty VMT growth between 1990 and 2015 would likely have been even higher.

gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder.

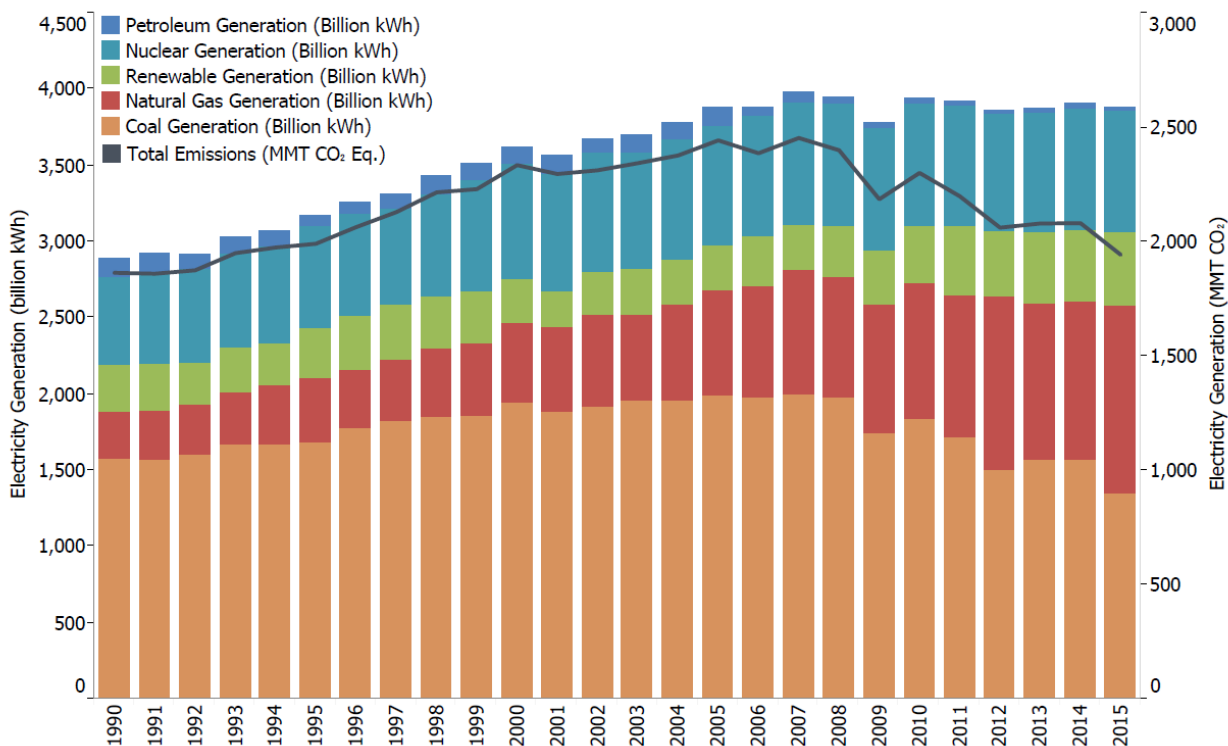
Industrial End-Use Sector. Industrial CO₂ emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 27 percent of CO₂ from fossil fuel combustion in 2015. Approximately 59 percent of these emissions 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 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 20 and 18 percent, respectively, of CO₂ emissions from fossil fuel combustion in 2015. Both sectors relied heavily on electricity for meeting energy demands, with 68 and 73 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 8 percent and 20 percent since 1990, respectively.

Electricity Generation. The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators consumed 34 percent of total U.S. energy uses from fossil fuels and emitted 38 percent of the CO₂ from fossil fuel combustion in 2015. The type of energy source used to generate electricity is the main factor influencing emissions. For example, some electricity is generated through non-fossil fuel options such as nuclear, hydroelectric, or geothermal energy. Including all electricity generation modes, electricity generators relied on coal for approximately 34 percent of their total energy requirements in 2015. In addition, the coal used by electricity generators accounted for 93 percent of all coal consumed for energy in the United States in 2015.¹⁶ 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. Including all electricity generation modes, electricity generators used natural gas for approximately 32 percent of their total energy requirements in 2015. 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. While emissions from the electric power sector have increased by approximately 4 percent since 1990, the carbon intensity of the electric power sector, in terms of CO₂ Eq. per QBtu has significantly decreased by 16 percent during that same timeframe. This trend away from a direct relationship between electricity generation and the resulting emissions is shown below in Figure ES-8.

¹⁶ See Table 6.2 Coal Consumption by Sector of EIA 2016.

Figure ES-8: Electricity Generation (Billion kWh) and Electricity Generation Emissions (MMT CO₂ Eq.)



Other significant CO₂ trends included the following:

- Carbon dioxide emissions from non-energy use of fossil fuels increased by 7.9 MMT CO₂ Eq. (6.8 percent) from 1990 through 2015. Emissions from non-energy uses of fossil fuels were 125.5 MMT CO₂ Eq. in 2015, which constituted 2.3 percent of total national CO₂ emissions, approximately the same proportion as in 1990.
- Carbon dioxide emissions from iron and steel production and metallurgical coke production have decreased by 52.6 MMT CO₂ Eq. (51.8 percent) from 1990 through 2015, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- Carbon dioxide emissions from ammonia production (10.8 MMT CO₂ Eq. in 2015) decreased by 2.2 MMT CO₂ Eq. (17.2 percent) since 1990. Ammonia production relies on natural gas as both a feedstock and a fuel, and as such, market fluctuations and volatility in natural gas prices affect the production of ammonia.
- Total C stock change (i.e., net CO₂ removals) in the LULUCF sector decreased by approximately 6.2 percent between 1990 and 2015. This decrease was primarily due to a decrease in the rate of net C accumulation in forest C stocks and an increase in emissions from *Land Converted to Settlements*.

Box ES-3: Use of Ambient Measurements Systems for Validation of Emission Inventories

In following the UNFCCC requirement under Article 4.1 to develop and submit national greenhouse gas emission 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.¹⁷ Several recent studies have measured

¹⁷ See <<http://www.ipcc-nggip.iges.or.jp/public/index.html>>.

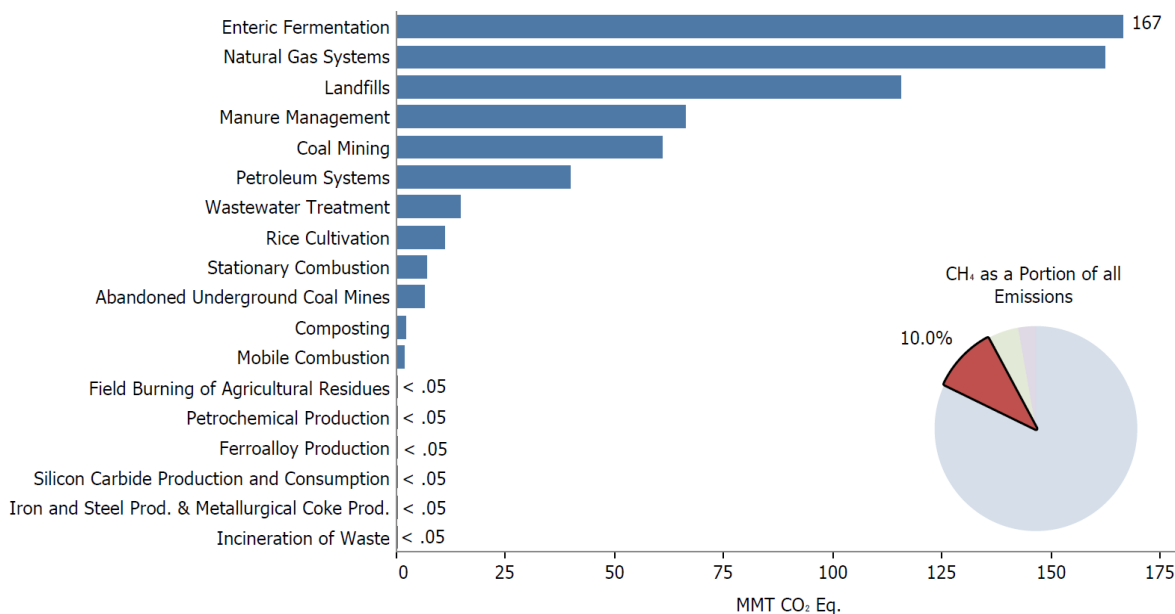
emissions at the national or regional level with results that sometimes differ from EPA’s estimate of emissions. EPA has engaged with researchers on how remote sensing, ambient measurement, and inverse modeling techniques for greenhouse gas emissions could assist in improving the understanding of inventory estimates. In working with the research community on ambient measurement and remote sensing techniques to improve national greenhouse gas inventories, EPA follows guidance from the IPCC on the use of measurements and modeling to validate emission inventories.¹⁸ An area of particular interest in EPA’s outreach efforts is how ambient measurement data can be used in a manner consistent with this Inventory report’s transparency on its calculation methodologies, and the ability of these techniques to attribute emissions and removals from remote sensing to anthropogenic sources, as defined by the IPCC for this report, versus natural sources and sinks.

In an effort to improve the ability to compare the national-level greenhouse gas inventory with measurement results that may be at other scales, a team at Harvard University along with EPA and other coauthors developed a gridded inventory of U.S. anthropogenic methane emissions with 0.1° x 0.1° spatial resolution, monthly temporal resolution, and detailed scale-dependent error characterization. The Inventory is designed to be consistent with the 1990 to 2014 U.S. EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks* estimates for the year 2012, which presents national totals for different source types.¹⁹

Methane Emissions

Methane (CH₄) is 25 times as effective as CO₂ at trapping heat in the atmosphere (IPCC 2007). Over the last two hundred and fifty years, the concentration of CH₄ in the atmosphere increased by 162 percent (IPCC 2013 and CDIAC 2016). Anthropogenic sources of CH₄ include natural gas and petroleum systems, agricultural activities, LULUCF, landfills, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-9).

Figure ES-9: 2015 Sources of CH₄ Emissions (MMT CO₂ Eq.)



Note: LULUCF emissions are reported separately from gross emissions totals and are not included in Figure ES-9. Refer to Table ES-5 for a breakout of LULUCF emissions by gas.

¹⁸ See <http://www.ipcc-nggip.iges.or.jp/meeting/pdfiles/1003_Uncertainty%20meeting_report.pdf>.

¹⁹ See <<https://www.epa.gov/ghgemissions/gridded-2012-methane-emissions>>.

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

- Enteric fermentation is the largest anthropogenic source of CH₄ emissions in the United States. In 2015, enteric fermentation CH₄ emissions were 166.5 MMT CO₂ Eq. (25.4 percent of total CH₄ emissions), which represents an increase of 2.4 MMT CO₂ Eq. (1.5 percent) since 1990. This increase in emissions from 1990 to 2015 generally follows the increasing trends in cattle populations. From 1990 to 1995, emissions increased and then generally decreased from 1996 to 2004, mainly due to fluctuations in beef cattle populations and increased digestibility of feed for feedlot cattle. Emissions increased from 2005 to 2007, as both dairy and beef populations increased. Research indicates that the feed digestibility of dairy cow diets decreased during this period. Emissions decreased again from 2008 to 2015 as beef cattle populations again decreased.
- Natural gas systems were the second largest anthropogenic source category of CH₄ emissions in the United States in 2015 with 162.4 MMT CO₂ Eq. of CH₄ emitted into the atmosphere. Those emissions have decreased by 31.6 MMT CO₂ Eq. (16.3 percent) since 1990. The decrease in CH₄ emissions is largely due to the decrease in emissions from transmission, storage, and distribution. The decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and fugitives). The decrease in distribution emissions is largely attributed to increased use of plastic piping, which has lower emissions than other pipe materials, and station upgrades at metering and regulating (M&R) stations.
- Landfills are the third largest anthropogenic source of CH₄ emissions in the United States (115.7 MMT CO₂ Eq.), accounting for 17.6 percent of total CH₄ emissions in 2015. From 1990 to 2015, CH₄ emissions from landfills decreased by 63.8 MMT CO₂ Eq. (35.6 percent), with small increases occurring in some interim years. This downward trend in emissions coincided with increased landfill gas collection and control systems, and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in MSW landfills over the time series,²⁰ which has more than offset the additional CH₄ emissions that would have resulted from an increase in the amount of municipal solid waste landfilled.
- Methane emissions from manure management, the fourth largest anthropogenic source of CH₄ emissions in the United States, increased by 78.3 percent since 1990, from 37.2 MMT CO₂ Eq. in 1990 to 66.3 MMT CO₂ Eq. in 2015. 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.
- Methane emissions from petroleum systems in the United States (39.9 MMT CO₂ Eq.) accounted for 6.1 percent of total CH₄ emissions in 2015. From 1990 to 2015, CH₄ emissions from petroleum systems decreased by 15.6 MMT CO₂ Eq. (or 28.1 percent). Production segment CH₄ emissions have decreased by around 8 percent from 2014 levels, primarily due to decreases in emissions from associated gas venting and flaring.

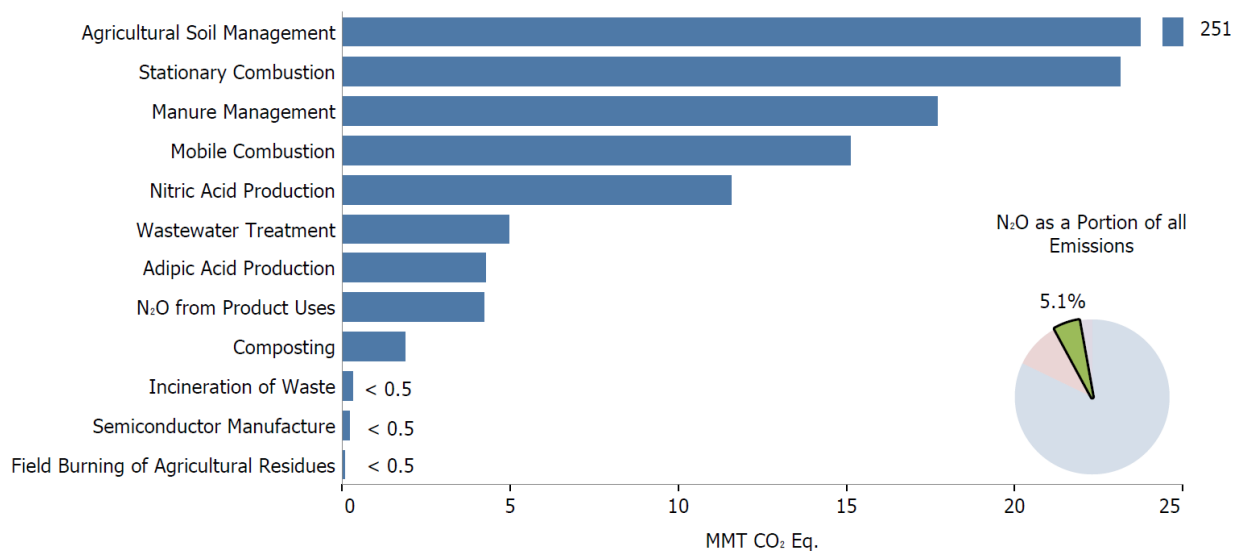
Nitrous Oxide Emissions

Nitrous oxide (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 nearly 300 times more powerful than CO₂ at trapping heat in the atmosphere (IPCC 2007). Since 1750, the global atmospheric concentration of N₂O has risen by approximately 21 percent (IPCC 2013 and CDIAC 2016). The main anthropogenic activities producing N₂O in the United States

²⁰ Carbon dioxide emissions from landfills are not included specifically in summing waste sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs and disposed wood products are accounted for in the estimates for LULUCF.

are agricultural soil management, stationary fuel combustion, fuel combustion in motor vehicles, manure management, and nitric acid production (see Figure ES-10).

Figure ES-10: 2015 Sources of N₂O Emissions (MMT CO₂ Eq.)



Note: LULUCF emissions are reported separately from gross emissions totals and are not included in Figure ES-10. Refer to Table ES-5 for a breakout of LULUCF emissions by gas.

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

- Agricultural soils accounted for approximately 75.1 percent of N₂O emissions and 3.8 percent of total emissions in the United States in 2015. Estimated emissions from this source in 2015 were 251.3 MMT CO₂ Eq. Annual N₂O emissions from agricultural soils fluctuated between 1990 and 2015, although overall emissions were 2.0 percent lower in 2015 than in 1990. Year-to-year fluctuations are largely a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.
- Nitrous oxide emissions from stationary combustion increased 11.2 MMT CO₂ Eq. (94.0 percent) from 1990 through 2015. Nitrous oxide 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 2015, total N₂O emissions from manure management were estimated to be 17.7 MMT CO₂ Eq.; emissions were 14.0 MMT CO₂ Eq. in 1990. These values include both direct and indirect N₂O emissions from manure management. Nitrous oxide emissions have remained fairly steady since 1990. Small changes in N₂O emissions from individual animal groups exhibit the same trends as the animal group populations, with the overall net effect that N₂O emissions showed a 26.6 percent increase from 1990 to 2015 and a 1.1 percent increase from 2014 through 2015.
- Nitrous oxide emissions from mobile combustion decreased by 26.1 MMT CO₂ Eq. (63.3 percent) from 1990 through 2015, primarily as a result of N₂O national emission control standards and emission control technologies for on-road vehicles.
- Nitrous oxide emissions from adipic acid production were 4.3 MMT CO₂ Eq. in 2015, and have decreased significantly since 1990 due to both the widespread installation of pollution control measures in the late 1990s and plant idling in the late 2000s. Emissions from adipic acid production have decreased by 72.0 percent since 1990 and by 74.8 percent since a peak in 1995.

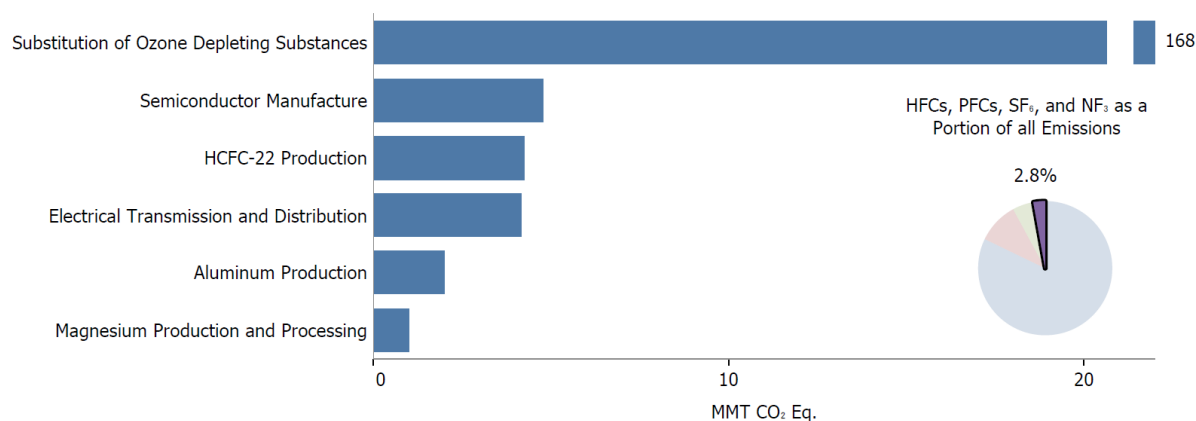
HFC, PFC, SF₆, and NF₃ Emissions

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are families of synthetic chemicals that are used as alternatives to ozone depleting substances (ODS), which are being phased out under the Montreal Protocol and Clean Air Act Amendments of 1990. Hydrofluorocarbons and PFCs do not deplete the stratospheric ozone layer, and are therefore acceptable alternatives under the Montreal Protocol on Substances that Deplete the Ozone Layer.

These compounds, however, along with SF₆ and NF₃, 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 2013).

Other emissive sources of these gases include HCFC-22 production, electrical transmission and distribution systems, semiconductor manufacturing, aluminum production, and magnesium production and processing (see Figure ES-11).

Figure ES-11: 2015 Sources of HFCs, PFCs, SF₆, and NF₃ Emissions (MMT CO₂ Eq.)



Some significant trends in U.S. HFC, PFC, SF₆, and NF₃ emissions include the following:

- Hydrofluorocarbon and perfluorocarbon emissions resulting from the substitution of ODS (e.g., chlorofluorocarbons [CFCs]) have been consistently increasing, from small amounts in 1990 to 168.5 MMT CO₂ Eq. in 2015. This increase was in large part the result of efforts to phase out CFCs and other ODS in the United States. In the short term, this trend is expected to continue, and will likely continue over the next decade as hydrochlorofluorocarbons (HCFCs), which are interim substitutes in many applications, are themselves phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol.
- GWP-weighted PFC, HFC, SF₆, and NF₃ emissions from semiconductor manufacturing have increased by 34.3 percent from 1990 to 2015, due to industrial growth and the adoption of emission reduction technologies. Within that time span, emissions peaked in 1999, the initial year of EPA's PFC Reduction/Climate Partnership for the Semiconductor Industry, but have since declined to 4.8 MMT CO₂ Eq. in 2015 (a 47.1 percent decrease relative to 1999).
- Sulfur hexafluoride emissions from electric power transmission and distribution systems decreased by 82.0 percent (19.0 MMT CO₂ Eq.) from 1990 to 2015. There are two potential causes for this decrease: (1) a sharp increase in the price of SF₆ during the 1990s and (2) a growing awareness of the environmental impact of SF₆ emissions through programs such as EPA's SF₆ Emission Reduction Partnership for Electric Power Systems.
- Perfluorocarbon emissions from aluminum production decreased by 90.7 percent (19.5 MMT CO₂ Eq.) from 1990 to 2015. This decline is due both to reductions in domestic aluminum production and to actions taken by aluminum smelting companies to reduce the frequency and duration of anode effects.

ES.3 Overview of Sector Emissions and Trends

In accordance with the UNFCCC decision to set the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) as the standard for Annex I countries at the Nineteenth Conference of the Parties (UNFCCC 2014), Figure ES-12 and Table ES-4 aggregate emissions and sinks by the sectors defined by those guidelines. Over the twenty-six-year period of 1990 to 2015, total emissions in the Energy, Industrial Processes and Product Use, and Agriculture grew by 221.0 MMT CO₂ Eq. (4.1 percent), 35.5 MMT CO₂ Eq. (10.4 percent), and 27.0 MMT CO₂ Eq. (5.5 percent), respectively. Over the same period, total emissions in the Waste sector decreased by 59.9 MMT CO₂ Eq. (30.1 percent) and estimates of net C sequestration in the LULUCF sector (magnitude of emissions plus CO₂ removals from all LULUCF source categories) decreased by 60.7 MMT CO₂ Eq. (7.4 percent).

Figure ES-12: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO₂ Eq.)

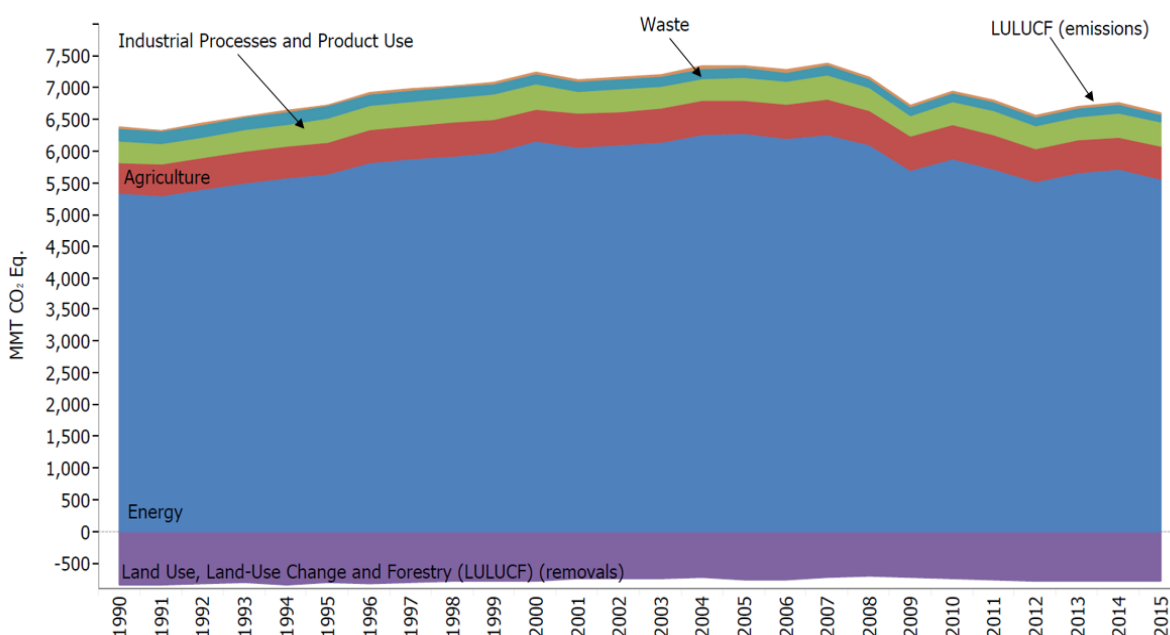


Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO₂ Eq.)

Chapter/IPCC Sector	1990	2005	2011	2012	2013	2014	2015
Energy	5,328.1	6,275.3	5,721.2	5,507.0	5,659.1	5,704.9	5,549.1
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Natural Gas Systems	231.8	189.8	190.2	191.4	197.7	204.9	204.8
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Petroleum Systems	59.0	49.9	52.2	50.3	48.2	46.6	43.4
Stationary Combustion	20.4	27.6	28.4	28.0	30.9	31.5	30.1
Mobile Combustion ^a	46.9	38.6	25.1	22.6	20.6	18.6	17.1
Incineration of Waste	8.4	12.9	10.9	10.7	10.7	10.9	11.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Industrial Processes and Product Use	340.4	353.4	371.0	360.9	363.7	379.8	375.9

Substitution of Ozone Depleting Substances	0.3	99.8	145.4	150.2	154.7	161.3	168.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.1	61.1	55.5	53.4	58.6	48.9
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.5	27.0	26.4	26.6	26.5	26.6	28.2
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Semiconductor Manufacture	3.6	4.7	4.9	4.5	4.1	5.0	5.0
Aluminum Production	28.3	7.6	6.8	6.4	6.2	5.4	4.8
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N ₂ O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Magnesium Production and Processing	5.2	2.7	2.8	1.7	1.5	1.1	1.0
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	495.3	526.4	541.9	525.9	516.9	514.7	522.3
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Manure Management	51.1	72.9	80.4	83.2	80.8	80.4	84.0
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Waste	199.3	158.2	142.6	144.4	140.4	140.2	139.4
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Wastewater Treatment	19.1	20.4	20.1	19.9	19.8	19.7	19.7
Composting	0.7	3.5	3.5	3.7	3.9	4.0	4.0
Total Emissions^b	6,363.1	7,313.3	6,776.7	6,538.3	6,680.1	6,739.7	6,586.7
Land Use, Land-Use Change, and Forestry	(819.6)	(731.0)	(749.2)	(753.8)	(763.0)	(761.4)	(758.9)
Forest Land	(784.3)	(729.8)	(733.8)	(723.6)	(733.5)	(731.8)	(728.7)
Cropland	2.4	(0.7)	4.0	1.3	3.1	4.0	4.7
Grassland	13.8	25.3	9.9	0.8	0.4	0.9	0.4
Wetlands	(3.9)	(5.2)	(3.9)	(4.0)	(4.0)	(4.0)	(4.1)
Settlements	(47.6)	(20.5)	(25.4)	(28.3)	(28.9)	(30.4)	(31.3)
Net Emissions (Sources and Sinks)^c	5,543.5	6,582.3	6,027.6	5,784.5	5,917.1	5,978.3	5,827.7

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

^a There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the

transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

^b Total emissions without LULUCF.

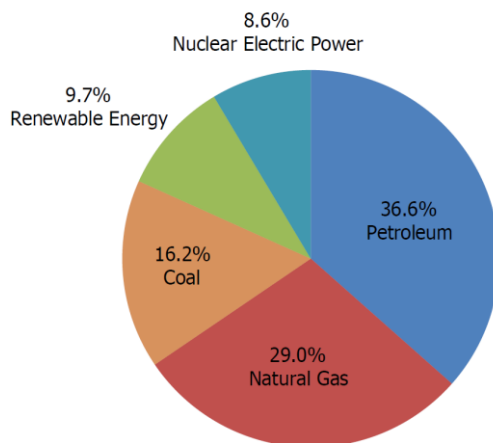
^c Total emissions with LULUCF.

Notes: 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, and the use of fossil fuels for non-energy purposes. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO₂ emissions for the period of 1990 through 2015. In 2015, approximately 82 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 18 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure ES-13). Energy-related activities are also responsible for CH₄ and N₂O emissions (42 percent and 12 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 84.2 percent of total U.S. greenhouse gas emissions in 2015.

Figure ES-13: 2015 U.S. Energy Consumption by Energy Source (Percent)



Industrial Processes and Product Use

The Industrial Processes and Product Use (IPPU) chapter includes greenhouse gas emissions occurring from industrial processes and from the use of greenhouse gases in products.

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. 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, 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, CO₂ consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, zinc production, and N₂O from product uses. Industrial processes also release HFCs, PFCs, SF₆, and NF₃ and other fluorinated compounds. In addition to the use of HFCs and some PFCs as ODS substitutes, HFCs, PFCs, SF₆, NF₃, and other fluorinated compounds are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Overall, emission

sources in the Industrial Process and Product Use chapter account for 5.7 percent of U.S. greenhouse gas emissions in 2015.

Agriculture

The Agriculture chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and some 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, liming, urea fertilization, and field burning of agricultural residues. In 2015, agricultural activities were responsible for emissions of 522.3 MMT CO₂ Eq., or 7.9 percent of total U.S. greenhouse gas emissions. Methane, nitrous oxide and carbon dioxide were the primary greenhouse gases emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented approximately 25.4 percent and 10.1 percent of total CH₄ emissions from anthropogenic activities, respectively, in 2015. Agricultural soil management activities, such as application of synthetic and organic fertilizers, deposition of livestock manure, and growing N-fixing plants, were the largest source of U.S. N₂O emissions in 2015, accounting for 75.1 percent. Carbon dioxide emissions from the application of crushed limestone and dolomite (i.e., soil liming) and urea fertilization represented 0.2 percent of total CO₂ emissions from anthropogenic activities. Figure 2-11 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

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 managed lands in the United States. Overall, managed land is a net sink for CO₂ (C sequestration) in the United States. The primary drivers of fluxes on managed lands include, for example, forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings and food scraps, and activities that cause changes in C stocks in coastal wetlands. The main drivers for forest C sequestration include forest growth and increasing forest area, as well as a net accumulation of C stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements*, which occurs predominantly from urban forests and landfilled yard trimmings and food scraps, is a result of net tree growth and increased urban forest size, as well as long-term accumulation of yard trimmings and food scraps carbon in landfills.

The LULUCF sector in 2015 resulted in a net increase in C stocks (i.e., net CO₂ removals) of 778.7 MMT CO₂ Eq. (Table ES-5).²¹ This represents an offset of 11.8 percent of total (i.e., gross) greenhouse gas emissions in 2015. Emissions of CH₄ and N₂O from LULUCF activities in 2015 are 19.7 MMT CO₂ Eq. and represent 0.3 percent of total greenhouse gas emissions.²² Between 1990 and 2015, total C sequestration in the LULUCF sector decreased by 6.2 percent, primarily due to a decrease in the rate of net C accumulation in forests and an increase in CO₂ emissions from *Land Converted to Settlements*.

Carbon dioxide removals from C stock changes are presented in Table ES-5 along with CH₄ and N₂O emissions for LULUCF source categories. Forest fires were the largest source of CH₄ emissions from LULUCF in 2015, totaling 7.3 MMT CO₂ Eq. (292 kt of CH₄). *Coastal Wetlands Remaining Coastal Wetlands* resulted in CH₄ emissions of 3.6 MMT CO₂ Eq. (143 kt of CH₄). Grassland fires resulted in CH₄ emissions of 0.4 MMT CO₂ Eq. (16 kt of CH₄). *Peatlands Remaining Peatlands, Land Converted to Wetlands, and Drained Organic Soils* resulted in CH₄ emissions of less than 0.05 MMT CO₂ Eq each.

²¹ LULUCF Carbon Stock Change is the net C stock change from the following categories: *Forest Land Remaining Forest Land, Land Converted to Forest Land, Cropland Remaining Cropland, Land Converted to Cropland, Grassland Remaining Grassland, Land Converted to Grassland, Wetlands Remaining Wetlands, Land Converted to Wetlands, Settlements Remaining Settlements*, and *Land Converted to Settlements*.

²² LULUCF emissions include the CH₄ and N₂O emissions reported for *Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and Coastal Wetlands Remaining Coastal Wetlands*; CH₄ emissions from *Land Converted to Coastal Wetlands*; and N₂O emissions from *Forest Soils and Settlement Soils*.

Forest fires were also the largest source of N₂O emissions from LULUCF in 2015, totaling 4.8 MMT CO₂ Eq. (16 kt of N₂O). Nitrous oxide emissions from fertilizer application to settlement soils in 2015 totaled to 2.5 MMT CO₂ Eq. (8 kt of N₂O). This represents an increase of 76.6 percent since 1990. Additionally, the application of synthetic fertilizers to forest soils in 2015 resulted in N₂O emissions of 0.5 MMT CO₂ Eq. (2 kt of N₂O). Nitrous oxide 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. Grassland fires resulted in N₂O emissions of 0.4 MMT CO₂ Eq. (1 kt of N₂O). *Coastal Wetlands Remaining Coastal Wetlands* and *Drained Organic Soils* resulted in N₂O emissions of 0.1 MMT CO₂ Eq. each (less than 0.5 kt of N₂O), and *Peatlands Remaining Peatlands* resulted in N₂O emissions of less than 0.05 MMT CO₂ Eq.

Table ES-5: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO₂ Eq.)

Gas/Land-Use Category	1990	2005	2011	2012	2013	2014	2015
Carbon Stock Change^a	(830.2)	(754.0)	(769.1)	(779.8)	(782.2)	(781.1)	(778.7)
Forest Land Remaining Forest Land	(697.7)	(664.6)	(670.0)	(666.9)	(670.8)	(669.3)	(666.2)
Land Converted to Forest Land	(92.0)	(81.4)	(75.8)	(75.2)	(75.2)	(75.2)	(75.2)
Cropland Remaining Cropland	(40.9)	(26.5)	(19.1)	(21.4)	(19.6)	(18.7)	(18.0)
Land Converted to Cropland	43.3	25.9	23.2	22.7	22.7	22.7	22.7
Grassland Remaining Grassland	(4.2)	5.5	(12.5)	(20.8)	(20.5)	(20.4)	(20.9)
Land Converted to Grassland	17.9	19.2	20.7	20.4	20.5	20.5	20.5
Wetlands Remaining Wetlands	(7.6)	(8.9)	(7.6)	(7.7)	(7.8)	(7.8)	(7.8)
Land Converted to Wetlands	+	+	+	+	+	+	+
Settlements Remaining Settlements	(86.2)	(91.4)	(98.7)	(99.2)	(99.8)	(101.2)	(102.1)
Land Converted to Settlements	37.2	68.4	70.7	68.3	68.3	68.3	68.3
CH₄	6.7	13.3	11.2	14.9	11.0	11.3	11.3
Forest Land Remaining Forest Land:							
Forest Fires	3.2	9.4	6.8	10.8	7.2	7.3	7.3
Wetlands Remaining Wetlands: Coastal							
Wetlands Remaining Coastal Wetlands	3.4	3.5	3.5	3.5	3.6	3.6	3.6
Grassland Remaining Grassland:							
Grass Fires	0.1	0.3	0.8	0.6	0.2	0.4	0.4
Forest Land Remaining Forest Land:							
Drained Organic Soils	+	+	+	+	+	+	+
Land Converted to Wetlands: Land							
Converted to Coastal Wetlands	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Peatlands							
Remaining Peatlands	+	+	+	+	+	+	+
N₂O	3.9	9.7	8.7	11.1	8.2	8.4	8.4
Forest Land Remaining Forest Land:							
Forest Fires	2.1	6.2	4.5	7.1	4.7	4.8	4.8
Settlements Remaining Settlements:							
Settlement Soils ^b	1.4	2.5	2.6	2.7	2.6	2.5	2.5
Forest Land Remaining Forest Land:							
Forest Soils ^c	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Grassland Remaining Grassland:							
Grass Fires	0.1	0.3	0.9	0.6	0.2	0.4	0.4
Wetlands Remaining Wetlands: Coastal							
Wetlands Remaining Coastal Wetlands	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Forest Land Remaining Forest Land:							
Drained Organic Soils	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands: Peatlands							
Remaining Peatlands	+	+	+	+	+	+	+
LULUCF Emissions^d	10.6	23.0	19.9	26.1	19.2	19.7	19.7
LULUCF Carbon Stock Change^a	(830.2)	(754.0)	(769.1)	(779.8)	(782.2)	(781.1)	(778.7)
LULUCF Sector Net Total^e	(819.6)	(731.0)	(749.2)	(753.8)	(763.0)	(761.4)	(758.9)

+ Absolute value does not exceed 0.05 MMT CO₂ Eq.

^a LULUCF Carbon Stock Change is the net C stock change from the following categories: *Forest Land Remaining Forest Land, Land Converted to Forest Land, Cropland Remaining Cropland, Land Converted to Cropland, Grassland Remaining Grassland, Land Converted to Grassland, Wetlands Remaining Wetlands, Land Converted to Wetlands, Settlements Remaining Settlements, and Land Converted to Settlements.*

- ^b Estimates include emissions from N fertilizer additions on both *Settlements Remaining Settlements* and *Land Converted to Settlements*.
- ^c Estimates include emissions from N fertilizer additions on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*.
- ^d LULUCF emissions include the CH₄ and N₂O emissions reported for *Peatlands Remaining Peatlands*, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH₄ emissions from *Land Converted to Coastal Wetlands*; and N₂O emissions from Forest Soils and Settlement Soils.
- ^e The LULUCF Sector Net Total is the net sum of all CH₄ and N₂O emissions to the atmosphere plus net carbon stock changes.
- Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

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 83.0 percent of this chapter's emissions, and 17.6 percent of total U.S. CH₄ emissions.²³ Additionally, wastewater treatment accounts for 14.2 percent of Waste emissions, 2.3 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 2.1 MMT CO₂ Eq. and 1.9 MMT CO₂ Eq., respectively. Overall, emission sources accounted for in the Waste chapter generated 2.1 percent of total U.S. greenhouse gas emissions in 2015.

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 five sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes and Product Use; Agriculture; LULUCF; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines and to promote comparability across countries, it is also useful to characterize emissions according to commonly used economic sector categories: residential, commercial, industry, transportation, electricity generation, agriculture, and U.S. Territories.

Table ES-6 summarizes emissions from each of these economic sectors, and Figure ES-14 shows the trend in emissions by sector from 1990 to 2015.

²³ Landfills also store carbon, due to incomplete degradation of organic materials such as harvest wood products, yard trimmings, and food scraps, as described in the Land-Use, Land-Use Change, and Forestry chapter of the Inventory report.

Figure ES-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO₂ Eq.)

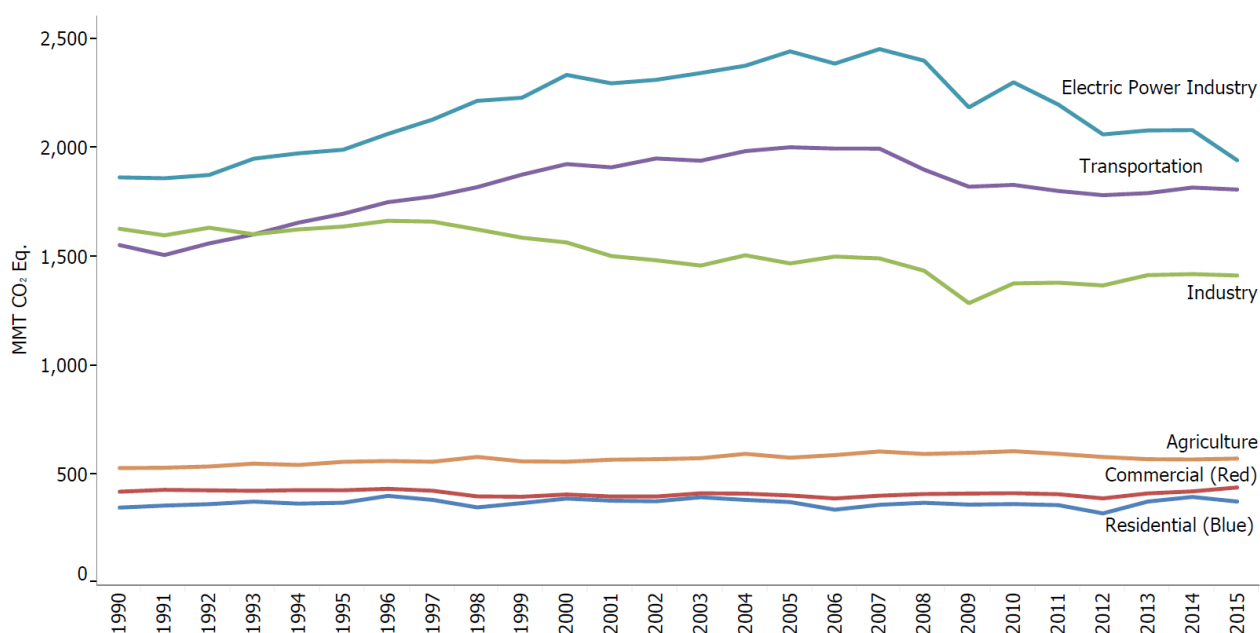


Table ES-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO₂ Eq.)

Economic Sectors	1990	2005	2011	2012	2013	2014	2015
Electric Power Industry	1,862.5	2,441.6	2,197.3	2,059.9	2,078.2	2,079.7	1,941.4
Transportation ^a	1,551.2	2,001.0	1,800.0	1,780.7	1,790.2	1,815.8	1,806.6
Industry ^a	1,626.3	1,467.1	1,378.6	1,365.9	1,413.4	1,418.0	1,411.6
Agriculture	526.7	574.3	592.0	577.6	567.5	566.1	570.3
Commercial ^a	418.1	400.7	406.5	387.3	410.1	419.5	437.4
Residential	344.9	370.4	356.3	318.4	372.6	393.9	372.7
U.S. Territories	33.3	58.1	46.0	48.5	48.1	46.6	46.6
Total Emissions	6,363.1	7,313.3	6,776.7	6,538.3	6,680.1	6,739.7	6,586.7
LULUCF Sector Net Total^b	(819.6)	(731.0)	(749.2)	(753.8)	(763.0)	(761.4)	(758.9)
Net Emissions (Sources and Sinks)	5,543.5	6,582.3	6,027.6	5,784.5	5,917.1	5,978.3	5,827.7

Notes: Total emissions presented without LULUCF. Total net emissions presented with LULUCF.

^a There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

^b The LULUCF Sector Net Total is the net sum of all CH₄ and N₂O emissions to the atmosphere plus net carbon stock changes.

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

Using this categorization, emissions from electricity generation accounted for the largest portion (29 percent) of total U.S. greenhouse gas emissions in 2015. Transportation activities, in aggregate, accounted for the second largest portion (27 percent), while emissions from industry accounted for the third largest portion (21 percent) of total U.S. greenhouse gas emissions in 2015. Emissions from industry have in general declined over the past decade, due to a number of factors, including 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 22 percent of U.S. greenhouse gas emissions were contributed by, in order of magnitude, the agriculture, commercial, and residential sectors, plus emissions from U.S. Territories. Activities related to agriculture accounted for 9 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 7 percent and 6 percent of emissions, respectively, 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, landfilling of yard trimmings, and changes in C stocks in coastal wetlands.

Electricity is ultimately consumed in the economic sectors described above. Table ES-7 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.²⁴ 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 and transportation account for the largest shares of U.S. greenhouse gas emissions (29 percent and 27 percent, respectively) in 2015. The residential and commercial sectors contributed the next largest shares of total U.S. greenhouse gas emissions in 2015. 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). 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-15 shows the trend in these emissions by sector from 1990 to 2015.

Table ES-7: U.S. Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (MMT CO₂ Eq.)

Implied Sectors	1990	2005	2011	2012	2013	2014	2015
Industry ^a	2,293.9	2,178.1	1,973.6	1,926.7	1,977.4	1,978.7	1,931.1
Transportation ^a	1,554.4	2,005.9	1,804.3	1,784.7	1,794.3	1,820.0	1,810.4
Commercial ^a	968.4	1,217.6	1,158.1	1,100.6	1,128.5	1,139.9	1,114.8
Residential	951.5	1,241.3	1,161.5	1,057.2	1,122.0	1,143.7	1,071.6
Agriculture	561.5	612.4	633.1	620.6	609.9	610.8	612.0
U.S. Territories	33.3	58.1	46.0	48.5	48.1	46.6	46.6
Total Emissions	6,363.1	7,313.3	6,776.7	6,538.3	6,680.1	6,739.7	6,586.7
LULUCF Sector Net Total^b	(819.6)	(731.0)	(749.2)	(753.8)	(763.0)	(761.4)	(758.9)
Net Emissions (Sources and Sinks)	5,543.5	6,582.3	6,027.6	5,784.5	5,917.1	5,978.3	5,827.7

^a There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

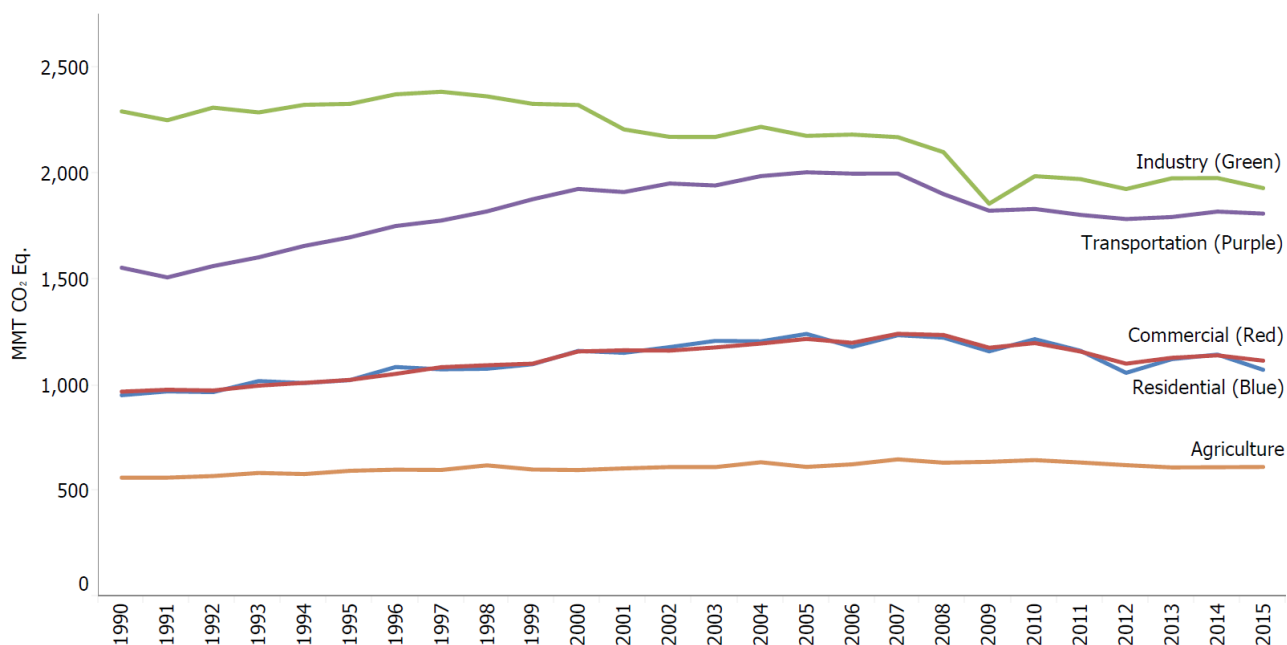
^b The LULUCF Sector Net Total is the net sum of all CH₄ and N₂O emissions to the atmosphere plus net carbon stock changes.

Notes: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector.

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

²⁴ 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.

Figure ES-15: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO₂ Eq.)



Box ES-4: 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 non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2015; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

Table ES-8 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.2 percent since 1990. Since 1990, this rate is slightly slower than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product (GDP) and national population (see Figure ES-16). These trends vary relative to 2005, when greenhouse gas emissions, total energy and fossil fuel consumption began to peak. Greenhouse gas emissions in the United States have decreased at an average annual rate of 1.0 percent since 2005. Total energy and fossil fuel consumption have also decreased at slower rates than emissions since 2005, while electricity consumption, GDP, and national population continued to increase.

Table ES-8: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	2005	2011	2012	2013	2014	2015	Avg. Annual Change since 1990	Avg. Annual Change since 2005
Greenhouse Gas Emissions ^a	100	115	107	103	105	106	104	0.2%	-1.0%
Energy Consumption ^b	100	118	115	112	115	117	115	0.6%	-0.2%
Fossil Fuel Consumption ^b	100	119	110	107	110	111	110	0.4%	-0.7%
Electricity Consumption ^b	100	134	137	135	136	138	137	1.3%	0.3%
GDP ^c	100	159	168	171	174	178	183	2.5%	1.4%
Population ^d	100	118	125	126	126	127	128	1.0%	0.8%

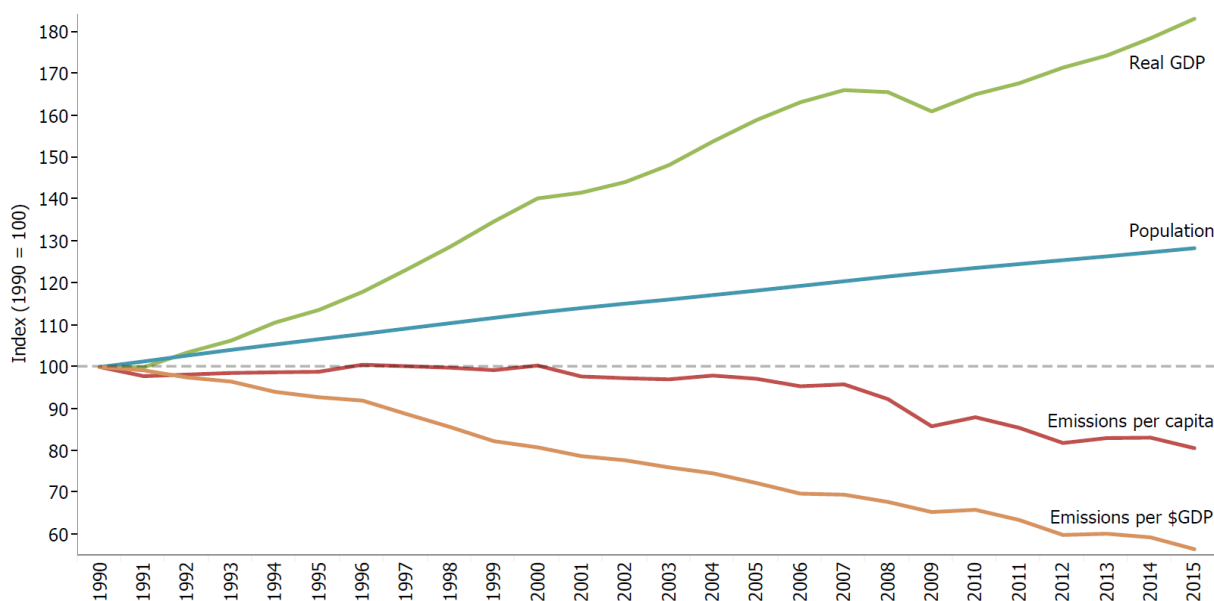
^a GWP-weighted values

^b Energy content-weighted values (EIA 2016)

^c Gross Domestic Product in chained 2009 dollars (BEA 2017)

^d U.S. Census Bureau (2016)

Figure ES-16: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product (GDP)



Source: BEA (2017), U.S. Census Bureau (2016), and emission estimates in this report.

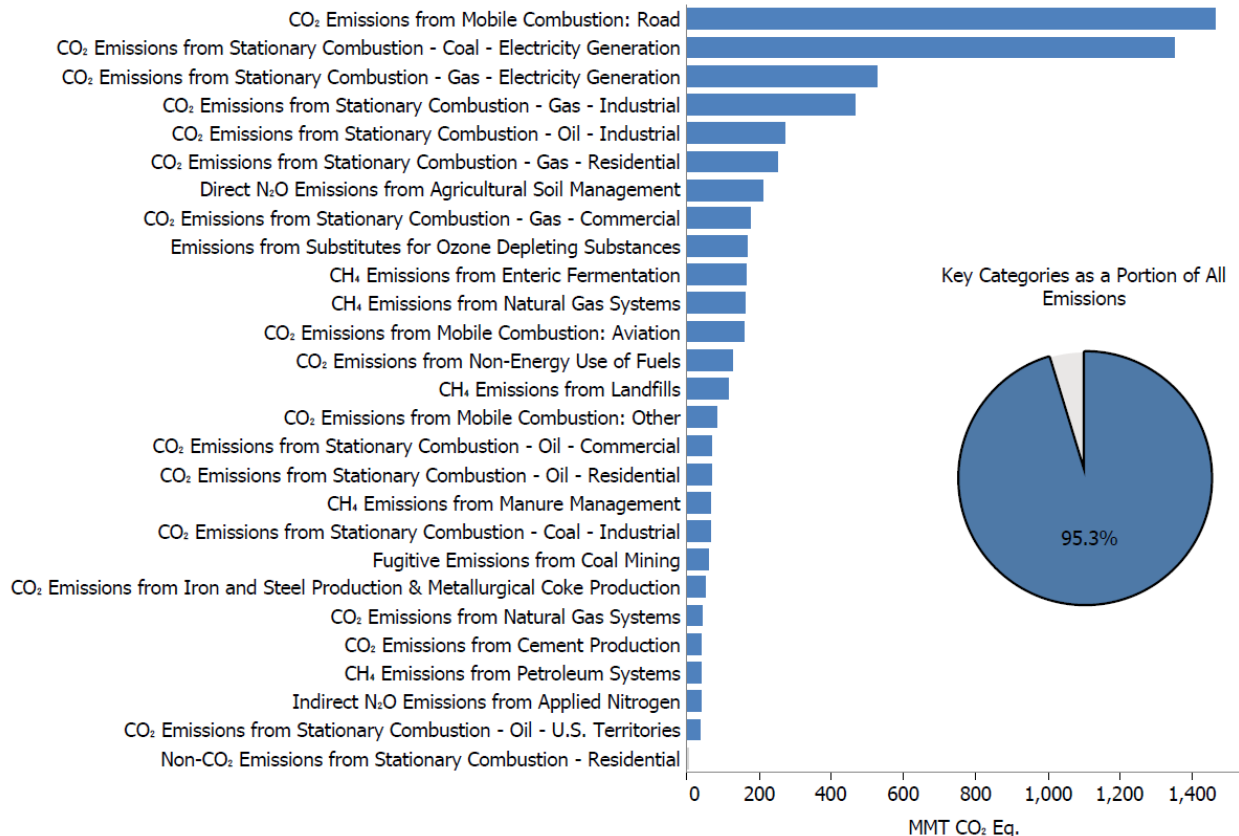
Key Categories

The 2006 IPCC Guidelines (IPCC 2006) defines a key category as a “[category] that is prioritized within the national inventory system because its estimate has a significant influence on a country’s total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals.”²⁵ 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-17 presents 2015 emission estimates for the key categories as defined by a level analysis (i.e., the absolute value of 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 – Key Categories and Annex 1.

²⁵ See Chapter 4 “Methodological Choice and Identification of Key Categories” in IPCC (2006). See <<http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html>>.

Figure ES-17: 2015 Key Categories (MMT CO₂ Eq.)



Note: For a complete discussion of the key category analysis, see Annex 1. Blue bars indicate either an Approach 1, or Approach 1 and Approach 2 level assessment key category. Gray bars indicate solely an Approach 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. The procedures followed for the Inventory have been formalized in accordance with the *Quality Assurance/Quality Control and Uncertainty Management Plan (QA/QC Management Plan)* for the Inventory, and the UNFCCC reporting guidelines. The QA process includes expert and public reviews for both the Inventory estimates and the Inventory report.

Uncertainty Analysis of Emission Estimates

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals, because they help to prioritize future work and improve overall quality. Some of the current estimates, such as those for CO₂ emissions from energy-related activities, are considered to have low uncertainties. This is because the amount of CO₂ emitted from energy-related activities is directly related to the amount of fuel consumed, the fraction of the fuel that is oxidized, and the carbon content of the fuel and, for the United States, the uncertainties associated with estimating those factors is believed to be relatively small. For some other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated increases the uncertainty or systematic error associated with the estimates presented. Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the *2006 IPCC Guidelines (IPCC 2006)*, Volume 1, Chapter 3 and require that countries provide single estimates of uncertainty for source and sink categories.

In addition to quantitative uncertainty assessments provided in accordance with UNFCCC reporting guidelines, 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.

Box ES-5: 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 2014) 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.
