

1 Executive Summary

2 An emissions inventory that identifies and quantifies a country's primary anthropogenic¹ sources and sinks of
3 greenhouse gases is essential for addressing climate change. This inventory adheres to both 1) a comprehensive and
4 detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and 2) a common
5 and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change
6 (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate
7 change.

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

15 Parties to the Convention, by ratifying, “shall develop, periodically update, publish and make available...national
16 inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by
17 the *Montreal Protocol*, using comparable methodologies...”³ The United States views this report as an opportunity
18 to fulfill these commitments.

19 This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990
20 through 2007. To ensure that the U.S. emissions inventory is comparable to those of other UNFCCC Parties, the
21 estimates presented here were calculated using methodologies consistent with those recommended in the *Revised*
22 *1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the *IPCC Good*
23 *Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the
24 *IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003). Additionally, the U.S.
25 emission inventory has begun to incorporate new methodologies and data from the *2006 IPCC Guidelines for*
26 *National Greenhouse Gas Inventories* (IPCC 2006). The structure of this report is consistent with the UNFCCC
27 guidelines for inventory reporting.⁴ For most source categories, the Intergovernmental Panel on Climate Change
28 (IPCC) methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

29
30 [BEGIN BOX]

31 Box ES- 1: Recalculations of Inventory Estimates

32 Each year, emission and sink estimates are recalculated and revised for all years in the Inventory of U.S.
33 Greenhouse Gas Emissions and Sinks, as attempts are made to improve both the analyses themselves, through the
34 use of better methods or data, and the overall usefulness of the report. In this effort, the United States follows the

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/cop8/08.pdf>>.

1 IPCC *Good Practice Guidance* (IPCC 2000), which states, regarding recalculations of the time series, "It is good
2 practice to recalculate historic emissions when methods are changed or refined, when new source categories are
3 included in the national inventory, or when errors in the estimates are identified and corrected." In general,
4 recalculations are made to the U.S. greenhouse gas emission estimates either to incorporate new methodologies or,
5 most commonly, to update recent historical data.

6 In each Inventory report, the results of all methodology changes and historical data updates are presented in the
7 "Recalculations and Improvements" chapter; detailed descriptions of each recalculation are contained within each
8 source's description contained in the report, if applicable. In general, when methodological changes have been
9 implemented, the entire time series (in the case of the most recent inventory report, 1990 through 2006) has been
10 recalculated to reflect the change, per IPCC *Good Practice Guidance*. Changes in historical data are generally the
11 result of changes in statistical data supplied by other agencies. References for the data are provided for additional
12 information.

13 [END BOX]

14

15 **Background Information**

16 Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide
17 (N₂O), and ozone (O₃). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are
18 also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons
19 (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that
20 contain bromine are referred to as bromofluorocarbons (i.e., halons). As stratospheric ozone depleting substances,
21 CFCs, HCFCs, and halons are covered under the *Montreal Protocol on Substances that Deplete the Ozone Layer*.
22 The UNFCCC defers to this earlier international treaty. Consequently, Parties to the UNFCCC are not required to
23 include these gases in their national greenhouse gas emission inventories.⁵ Some other fluorine-containing
24 halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—do
25 not deplete stratospheric ozone but are potent greenhouse gases. These latter substances are addressed by the
26 UNFCCC and accounted for in national greenhouse gas emission inventories.

27 There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial and/or
28 solar radiation absorption by influencing the formation or destruction of greenhouse gases, including tropospheric
29 and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and non-CH₄
30 volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as
31 those produced by sulfur dioxide (SO₂) or elemental carbon emissions, can also affect the absorptive characteristics
32 of the atmosphere.

33 Although the direct greenhouse gases CO₂, CH₄, and N₂O occur naturally in the atmosphere, human activities have
34 changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2005,
35 concentrations of these greenhouse gases have increased globally by 36, 148, and 18 percent, respectively (IPCC
36 2007).

37 Beginning in the 1950s, the use of CFCs and other stratospheric ozone depleting substances (ODS) increased by
38 nearly 10 percent per year until the mid-1980s, when international concern about ozone depletion led to the entry
39 into force of the *Montreal Protocol*. Since then, the production of ODS is being phased out. In recent years, use of
40 ODS substitutes such as HFCs and PFCs has grown as they begin to be phased in as replacements for CFCs and
41 HCFCs. Accordingly, atmospheric concentrations of these substitutes have been growing (IPCC 2007).

⁵ Emissions estimates of CFCs, HCFCs, halons and other ozone-depleting substances are included in the annexes of the Inventory report for informational purposes.

1 Global Warming Potentials

2 Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur
3 when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the
4 substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or
5 when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or
6 albedo).⁶ The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each
7 greenhouse gas to trap heat in the atmosphere relative to another gas.

8 The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous
9 release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct
10 radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO₂, and therefore GWP-
11 weighted emissions are measured in teragrams of CO₂ equivalent (Tg CO₂ Eq.).^{7,8} All gases in this Executive
12 Summary are presented in units of Tg CO₂ Eq.

13 The UNFCCC reporting guidelines for national inventories were updated in 2002,⁹ but continue to require the use
14 of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). This requirement ensures that current
15 estimates of aggregate greenhouse gas emissions for 1990 to 2007 are consistent with estimates developed prior to
16 the publication of the IPCC Third Assessment Report (TAR) and the IPCC Fourth Assessment Report (AR4).
17 Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are
18 reported by the United States using SAR GWP values. All estimates are provided throughout the report in both CO₂
19 equivalents and unweighted units. A comparison of emission values using the SAR GWPs versus the TAR and
20 AR4 GWPs can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in
21 this report are listed below in Table ES-1.

22 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

23 Source: IPCC (1996)

⁶ 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.

⁷ Carbon comprises 12/44^{ths} of carbon dioxide by weight.

⁸ One teragram is equal to 10¹² grams or one million metric tons.

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

* 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.

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).

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

In 2007, total U.S. greenhouse gas emissions were 7,125.2 Tg CO₂ Eq. Overall, total U.S. emissions have risen by 17.1 percent from 1990 to 2007. Emissions rose from 2006 to 2007, increasing by 1.4 percent (96.6 Tg CO₂ Eq.). The following factors were primary contributors to this increase: (1) cooler winter and warmer summer conditions in 2007 than in 2006 increased the demand for heating fuels and contributed to the increase in the demand for electricity, (2) increased consumption of fossil fuels to generate electricity and (3) a significant decrease (14.2 percent) in hydropower generation used to meet this demand.

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 2007.

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 CO₂ Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007
CO₂	5,063.0	5,389.8	5,940.6	6,080.3	6,000.0	6,085.9
Fossil Fuel Combustion	4,717.4	5,025.7	5,575.6	5,733.9	5,646.5	5,747.6
Electricity Generation	1,809.7	1,938.9	2,283.2	2,381.0	2,327.3	2,397.2
Transportation	1,484.5	1,598.7	1,800.3	1,881.5	1,880.9	1,887.4
Industrial	842.7	874.4	858.6	838.5	855.6	857.2
Residential	337.7	354.4	370.4	358.0	321.9	340.6
Commercial	214.5	224.4	226.9	221.8	206.0	214.4
U.S. Territories	28.3	35.0	36.2	53.2	54.8	50.8
Non-Energy Use of Fuels	117.0	134.3	142.5	142.1	144.6	130.2
Iron and Steel Production	87.2	75.8	67.7	47.5	50.0	51.3
Cement Production	33.3	36.8	41.2	45.9	46.6	44.5
Natural Gas Systems	33.7	33.8	29.4	29.5	29.5	28.7
Waste Incineration	10.9	15.7	17.5	19.5	19.8	20.8
Lime Production	11.5	13.3	14.1	14.4	15.1	14.6
Ammonia Production and Urea Consumption	16.8	17.8	16.4	12.8	12.3	13.8
Cropland Remaining Cropland	7.1	7.0	7.5	7.9	7.9	8.0
Limestone and Dolomite Use	5.5	7.3	5.8	7.4	8.6	6.6
Aluminum Production	6.8	5.7	6.1	4.1	3.8	4.3
Soda Ash Production and Consumption	4.1	4.3	4.2	4.2	4.2	4.1
Petrochemical Production	2.2	2.8	3.0	2.8	2.6	2.6

Titanium Dioxide Production	1.2	1.5	1.8	1.8	1.9	1.9
Carbon Dioxide Consumption	1.4	1.4	1.4	1.3	1.7	1.9
Ferroalloy Production	2.2	2.0	1.9	1.4	1.5	1.6
Phosphoric Acid Production	1.5	1.5	1.4	1.4	1.2	1.2
Wetlands Remaining Wetlands	1.0	1.0	1.2	1.1	0.9	1.0
Zinc Production	0.9	1.0	1.1	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.3	0.2	0.2	0.2	0.2
<i>Land Use, Land-Use Change, and Forestry (Sink)^a</i>	(883.3)	(819.4)	(766.6)	(1,137.8)	(1,065.6)	(1,077.7)
<i>Biomass—Wood^b</i>	215.2	229.1	218.1	208.9	209.9	209.8
<i>International Bunker Fuels^b</i>	114.3	101.6	99.0	111.5	110.5	108.8
<i>Biomass—Ethanol^b</i>	4.2	7.7	9.2	22.6	30.5	38.0
CH₄	616.9	615.5	591.1	558.6	575.1	578.7
Enteric Fermentation	133.2	143.6	134.4	136.0	138.2	139.0
Landfills	149.2	144.3	122.3	127.8	130.4	132.9
Natural Gas Systems	129.6	132.6	130.8	106.3	104.8	104.7
Coal Mining	84.1	67.1	60.5	57.1	58.4	57.6
Manure Management	30.4	34.5	37.9	41.8	41.9	44.0
Petroleum Systems	33.9	32.0	30.3	28.3	28.3	28.8
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4
Forest Land Remaining Forest Land	4.6	5.4	20.4	10.8	24.2	22.1
Stationary Combustion	7.4	7.2	6.6	6.7	6.3	6.6
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2
Abandoned Underground Coal Mines	6.0	8.2	7.4	5.6	5.5	5.7
Mobile Combustion	4.7	4.3	3.4	2.5	2.4	2.3
Composting	0.3	0.7	1.3	1.6	1.6	1.7
Petrochemical Production	0.9	1.1	1.2	1.1	1.0	1.0
Iron and Steel Production	1.3	1.3	1.2	1.0	0.9	0.9
Field Burning of Agricultural Residues	0.7	0.7	0.8	0.9	0.8	0.9
Ferroalloy Production	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+
<i>International Bunker Fuels^b</i>	0.2	0.1	0.1	0.1	0.1	0.1
N₂O	315.0	334.1	329.2	315.6	311.4	311.2
Agricultural Soil Management	200.3	202.3	204.5	210.6	208.5	207.9
Mobile Combustion	43.7	53.7	52.8	36.7	33.5	30.1
Nitric Acid Production	20.0	22.3	21.9	18.6	18.2	21.7
Stationary Combustion	12.8	13.4	14.6	14.8	14.6	14.7
Manure Management	12.1	12.9	14.0	14.2	14.6	14.7
Adipic Acid Production	15.3	17.3	6.2	5.9	5.9	5.9
Wastewater Treatment	3.7	4.0	4.5	4.8	4.8	4.9
N ₂ O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4
Forest Land Remaining Forest Land	0.5	0.7	2.4	1.4	2.8	2.6
Composting	0.4	0.8	1.4	1.7	1.8	1.8
Settlements Remaining Settlements	1.0	1.2	1.2	1.5	1.5	1.6
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5
Waste Incineration	0.5	0.5	0.4	0.4	0.4	0.4
Wetlands Remaining Wetlands	+	+	+	+	+	+
<i>International Bunker Fuels^b</i>	1.1	0.9	0.9	1.0	1.0	1.0
HFCs	36.9	61.8	100.1	116.1	119.1	125.5
Substitution of Ozone Depleting Substances ^c	0.3	28.5	71.2	100.0	105.0	108.3
HCFC-22 Production	36.4	33.0	28.6	15.8	13.8	17.0

Semiconductor Manufacture	0.2	0.3	0.3	0.2	0.3	0.3
PFCs	20.8	15.6	13.5	6.2	6.0	7.5
Aluminum Production	18.5	11.8	8.6	3.0	2.5	3.8
Semiconductor Manufacture	2.2	3.8	4.9	3.2	3.5	3.6
SF₆	32.8	28.1	19.2	17.9	17.0	16.5
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7
Magnesium Production and Processing	5.4	5.6	3.0	2.9	2.9	3.0
Semiconductor Manufacture	0.5	0.9	1.1	1.0	1.0	0.8
Total	6,085.5	6,444.8	6,993.8	7,094.7	7,028.7	7,125.2
Net Emissions (Sources and Sinks)	5,202.2	5,625.4	6,227.2	5,956.8	5,963.0	6,047.6

1 + Does not exceed 0.05 Tg CO₂ Eq.

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

4 ^b Emissions from International Bunker Fuels and Biomass Combustion are not included in totals.

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

6 Note: Totals may not sum due to independent rounding.

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

8
9 Figure ES-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2007. The
10 primary greenhouse gas emitted by human activities in the United States was CO₂, representing approximately 85.4
11 percent of total greenhouse gas emissions. The largest source of CO₂, and of overall greenhouse gas emissions, was
12 fossil fuel combustion. CH₄ emissions, which have declined from 1990 levels, resulted primarily from enteric
13 fermentation associated with domestic livestock, decomposition of wastes in landfills, and natural gas systems.
14 Agricultural soil management and mobile source fuel combustion were the major sources of N₂O emissions. The
15 emissions of substitutes for ozone depleting substances and emissions of HFC-23 during the production of HCFC-
16 22 were the primary contributors to aggregate HFC emissions. Electrical transmission and distribution systems
17 accounted for most SF₆ emissions, while PFC emissions resulted as a by-product of primary aluminum production
18 and from semiconductor manufacturing.

19
20 Figure ES-4: 2007 Greenhouse Gas Emissions by Gas (percents based on Tg CO₂ Eq.)
21

22 Overall, from 1990 to 2007, total emissions of CO₂ increased by 1,022.8 Tg CO₂ Eq. (20.2 percent), while CH₄ and
23 N₂O emissions decreased by 38.2 Tg CO₂ Eq. (6.2 percent) and 3.8 Tg CO₂ Eq. (1.2 percent), respectively. During
24 the same period, aggregate weighted emissions of HFCs, PFCs, and SF₆ rose by 59.0 Tg CO₂ Eq. (65.2 percent).
25 From 1990 to 2007, HFCs increased by 88.6 Tg CO₂ Eq. (240.0 percent), PFCs decreased by 13.3 Tg CO₂ Eq. (64.0
26 percent), and SF₆ decreased by 16.3 Tg CO₂ Eq. (49.8 percent). Despite being emitted in smaller quantities relative
27 to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF₆ are significant because many of them
28 have extremely high global warming potentials and, in the cases of PFCs and SF₆, long atmospheric lifetimes.
29 Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban
30 areas, agricultural soils, and landfilled yard trimmings and food scraps, which, in aggregate, offset 15.1 percent of
31 total emissions in 2007. The following sections describe each gas' contribution to total U.S. greenhouse gas
32 emissions in more detail.

33 Carbon Dioxide Emissions

34 The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of
35 CO₂ are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through
36 natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly
37 balanced. Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO₂ have risen
38 about 36 percent (IPCC 2007), principally due to the combustion of fossil fuels. Within the United States, fuel
39 combustion accounted for 94.4 percent of CO₂ emissions in 2007. Globally, approximately 29,195 Tg of CO₂ were

1 added to the atmosphere through the combustion of fossil fuels in 2006, of which the United States accounted for
2 about 20 percent.¹⁰ Changes in land use and forestry practices can also emit CO₂ (e.g., through conversion of forest
3 land to agricultural or urban use) or can act as a sink for CO₂ (e.g., through net additions to forest biomass).

4
5 Figure ES-5: 2007 Sources of CO₂ Emissions
6

7 As the largest source of U.S. greenhouse gas emissions, CO₂ from fossil fuel combustion has accounted for
8 approximately 79 percent of GWP-weighted emissions since 1990, growing slowly from 78 percent of total GWP-
9 weighted emissions in 1990 to 81 percent in 2007. Emissions of CO₂ from fossil fuel combustion increased at an
10 average annual rate of 1.2 percent from 1990 to 2007. The fundamental factors influencing this trend include (1) a
11 generally growing domestic economy over the last 17 years, and (2) significant overall growth in emissions from
12 electricity generation and transportation activities. Between 1990 and 2007, CO₂ emissions from fossil fuel
13 combustion increased from 4,717.4 Tg CO₂ Eq. to 5,747.6 Tg CO₂ Eq.—a 21.8 percent total increase over the
14 eighteen-year period. From 2006 to 2007, these emissions increased by 101.0 Tg CO₂ Eq. (1.8 percent).

15 Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S.
16 emission trends. Changes in CO₂ emissions from fossil fuel combustion are influenced by many long-term and
17 short-term factors, including population and economic growth, energy price fluctuations, technological changes, and
18 seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally
19 fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of
20 non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices,
21 severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric
22 dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic
23 performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

24
25 Figure ES-6: 2007 CO₂ Emissions from Fossil Fuel Combustion by Sector and Fuel Type
26

27 Figure ES-7: 2007 End-Use Sector Emissions of CO₂, CH₄, and N₂O from Fossil Fuel Combustion
28

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

37 Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the
38 individual end-use sectors.

¹⁰ Global CO₂ emissions from fossil fuel combustion were taken from Energy Information Administration *International Energy Annual 2006* (EIA 2008b).

1 Figure ES-6, Figure ES-7, and Table ES-3 summarize CO₂ emissions from fossil fuel combustion by end-use sector.

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

End-Use Sector	1990	1995	2000	2005	2006	2007
Transportation	1,487.5	1,601.7	1,803.7	1,886.2	1,885.4	1,892.2
Combustion	1,484.5	1,598.7	1,800.3	1,881.5	1,880.9	1,887.4
Electricity	3.0	3.0	3.4	4.7	4.5	4.8
Industrial	1,525.2	1,587.3	1,643.7	1,568.9	1,561.8	1,565.2
Combustion	842.7	874.4	858.6	838.5	855.6	857.2
Electricity	682.6	712.9	785.0	730.5	706.2	708.0
Residential	927.1	993.3	1,128.2	1,207.2	1,145.9	1,198.0
Combustion	337.7	354.4	370.4	358.0	321.9	340.6
Electricity	589.4	638.8	757.9	849.2	824.1	857.4
Commercial	749.2	808.5	963.8	1,018.4	998.6	1,041.4
Combustion	214.5	224.4	226.9	221.8	206.0	214.4
Electricity	534.7	584.1	736.8	796.6	792.5	827.1
U.S. Territories^a	28.3	35.0	36.2	53.2	54.8	50.8
Total	4,717.4	5,025.7	5,575.6	5,733.9	5,646.5	5,747.6
Electricity Generation	1,809.7	1,938.9	2,283.2	2,381.0	2,327.3	2,397.2

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

5 ^a Fuel consumption by U.S. territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other
6 U.S. Pacific Islands) is included in this report.
7

8 *Transportation End-Use Sector.* Transportation activities (excluding international bunker fuels) accounted for 33
9 percent of CO₂ emissions from fossil fuel combustion in 2007.¹¹ Virtually all of the energy consumed in this end-
10 use sector came from petroleum products. Nearly 60 percent of the emissions resulted from gasoline consumption
11 for personal vehicle use. The remaining emissions came from other transportation activities, including the
12 combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft.

13 *Industrial End-Use Sector.* Industrial CO₂ emissions, resulting both directly from the combustion of fossil fuels and
14 indirectly from the generation of electricity that is consumed by industry, accounted for 27 percent of CO₂ from
15 fossil fuel combustion in 2007. Just over half of these emissions resulted from direct fossil fuel combustion to
16 produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity
17 for motors, electric furnaces, ovens, lighting, and other applications.

18 *Residential and Commercial End-Use Sectors.* The residential and commercial end-use sectors accounted for 21
19 and 18 percent, respectively, of CO₂ emissions from fossil fuel combustion in 2007. Both sectors relied heavily on
20 electricity for meeting energy demands, with 72 and 79 percent, respectively, of their emissions attributable to
21 electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due
22 to the consumption of natural gas and petroleum for heating and cooking.

23 *Electricity Generation.* The United States relies on electricity to meet a significant portion of its energy demands,
24 especially for lighting, electric motors, heating, and air conditioning. Electricity generators consumed 36 percent of
25 U.S. energy from fossil fuels and emitted 42 percent of the CO₂ from fossil fuel combustion in 2007. The type of
26 fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is
27 generated with low CO₂ emitting energy technologies, particularly non-fossil options such as nuclear, hydroelectric,
28 or geothermal energy. However, electricity generators rely on coal for over half of their total energy requirements

¹¹ If emissions from international bunker fuels are included, the transportation end-use sector accounted for 35 percent of U.S. emissions from fossil fuel combustion in 2007.

1 and accounted for 94 percent of all coal consumed for energy in the United States in 2007. Consequently, changes
2 in electricity demand have a significant impact on coal consumption and associated CO₂ emissions.

3 Other significant CO₂ trends included the following:

- 4 • CO₂ emissions from non-energy use of fossil fuels have increased 13.3 Tg CO₂ Eq. (11 percent) from 1990
5 through 2007. Emissions from non-energy uses of fossil fuels were 130.2 Tg CO₂ Eq. in 2007, which
6 constituted 2.1 percent of total national CO₂ emissions, approximately the same proportion as in 1990.
- 7 • CO₂ emissions from iron and steel production increased slightly from 2006 to 2007 (1.3 Tg CO₂ Eq.), but have
8 decreased by 41 percent to 51.3 Tg CO₂ Eq. from 1990 through 2007, due to restructuring of the industry,
9 technological improvements, and increased scrap utilization.
- 10 • In 2007, CO₂ emissions from cement manufacture decreased slightly by 2.0 Tg CO₂ Eq. (4.4 percent) from
11 2006 to 2007. This decrease occurs despite the overall increase over the time series. After falling in 1991 by
12 two percent from 1990 levels, cement production emissions grew every year through 2006. Overall, from 1990
13 to 2007, emissions from cement manufacture increased by 34 percent, an increase of 11.2 Tg CO₂ Eq.
- 14 • CO₂ emissions from waste incineration (20.8 Tg CO₂ Eq. in 2007) increased by 9.8 Tg CO₂ Eq. (90 percent)
15 from 1990 through 2007, as the volume of plastics and other fossil carbon-containing materials in the waste
16 stream grew.
- 17 • Net CO₂ sequestration from Land Use, Land-Use Change, and Forestry increased by 194.4 Tg CO₂ Eq. (22
18 percent) from 1990 through 2007. This increase was primarily due to an increase in the rate of net carbon
19 accumulation in forest carbon stocks, particularly in aboveground and belowground tree biomass. Annual
20 carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of
21 carbon accumulation in urban trees increased.

22 Methane Emissions

23 According to the IPCC, CH₄ is more than 20 times as effective as CO₂ at trapping heat in the atmosphere. Over the
24 last two hundred and fifty years, the concentration of CH₄ in the atmosphere increased by 148 percent (IPCC 2007).
25 Anthropogenic sources of CH₄ include landfills, natural gas and petroleum systems, agricultural activities, coal
26 mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-8).

27

28 Figure ES-8: 2007 Sources of CH₄ Emissions

29

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

- 31 • Enteric Fermentation is the largest anthropogenic source of CH₄ emissions in the United States. In 2007,
32 enteric fermentation CH₄ emissions were 139.0 Tg CO₂ Eq. (approximately 24 percent of total CH₄ emissions),
33 which represents an increase of 5.8 Tg CO₂ Eq., or 4.3 percent, since 1990.
- 34 • Landfills are the second largest anthropogenic source of CH₄ emissions in the United States, accounting for
35 approximately 23 percent of total CH₄ emissions (132.9 Tg CO₂ Eq.) in 2007. From 1990 to 2007, net CH₄
36 emissions from landfills decreased by 16.3 Tg CO₂ Eq. (11 percent), with small increases occurring in some
37 interim years, including 2007. This downward trend in overall emissions is the result of increases in the
38 amount of landfill gas collected and combusted,¹² which has more than offset the additional CH₄ emissions

¹² The CO₂ produced from combusted landfill CH₄ at landfills is not counted in national inventories as it is considered part of the

1 resulting from an increase in the amount of municipal solid waste landfilled.

- 2 • CH₄ emissions from natural gas systems were 104.7 Tg CO₂ Eq. in 2007; emissions have declined by 24.9 Tg
3 CO₂ Eq. (19 percent) since 1990. This decline has been due to improvements in technology and management
4 practices, as well as some replacement of old equipment.
- 5 • In 2007, CH₄ emissions from coal mining were 57.6 Tg CO₂ Eq., a 0.8 Tg CO₂ Eq. (1.3 percent) decrease over
6 2006 emission levels. The overall decline of 26.4 Tg CO₂ Eq. (31 percent) from 1990 results from the mining
7 of less gassy coal from underground mines and the increased use of CH₄ collected from degasification systems.
- 8 • CH₄ emissions from manure management increased by 44.7 percent for CH₄, from 30.4 Tg CO₂ Eq. in 1990 to
9 44.0 Tg CO₂ Eq. in 2007. The majority of this increase was from swine and dairy cow manure, since the
10 general trend in manure management is one of increasing use of liquid systems, which tends to produce greater
11 CH₄ emissions. The increase in liquid systems is the combined result of a shift to larger facilities, and to
12 facilities in the West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the
13 application of manure nutrients have shifted manure management practices at smaller dairies from daily spread
14 to manure managed and stored on site.

15 Nitrous Oxide Emissions

16 N₂O is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in
17 the agricultural, energy-related, industrial, and waste management fields. While total N₂O emissions are much
18 lower than CO₂ emissions, N₂O is approximately 300 times more powerful than CO₂ at trapping heat in the
19 atmosphere. Since 1750, the global atmospheric concentration of N₂O has risen by approximately 18 percent (IPCC
20 2007). The main anthropogenic activities producing N₂O in the United States are agricultural soil management, fuel
21 combustion in motor vehicles, nitric acid production, stationary fuel combustion, manure management, and adipic
22 acid production (see Figure ES-9).

23
24 Figure ES-9: 2007 Sources of N₂O Emissions

25
26 Some significant trends in U.S. emissions of N₂O include the following:

- 27 • Agricultural soils produced approximately 67 percent of N₂O emissions in the United States in 2007. Estimated
28 emissions from this source in 2007 were 207.9 Tg CO₂ Eq. Annual N₂O emissions from agricultural soils
29 fluctuated between 1990 and 2007, although overall emissions were 3.8 percent higher in 2007 than in 1990.
30 N₂O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to
31 the amount of N applied to soils, which has not changed significantly over the time-period, and to weather
32 patterns and crop type.
- 33 • In 2007, N₂O emissions from mobile combustion were 30.1 Tg CO₂ Eq. (approximately 10 percent of U.S. N₂O
34 emissions). From 1990 to 2007, N₂O emissions from mobile combustion decreased by 31.1 percent. However,
35 from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced NO_x emissions
36 while increasing N₂O emissions. Since 1998, newer control technologies have led to a steady decline in N₂O
37 from this source.
- 38 • N₂O emissions from adipic acid production were 5.9 Tg CO₂ Eq. in 2007, and have decreased significantly
39 since 1996 from the widespread installation of pollution control measures. Emissions from adipic acid
40 production have decreased 61 percent since 1990, and emissions from adipic acid production have fluctuated by

natural C cycle of decomposition.

1 less than 1.2 Tg CO₂ Eq. annually since 1998.

2 HFC, PFC, and SF₆ Emissions

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

6 These compounds, however, along with SF₆, are potent greenhouse gases. In addition to having high global
7 warming potentials, SF₆ and PFCs have extremely long atmospheric lifetimes, resulting in their essentially
8 irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas
9 the IPCC has evaluated.

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

13

14 Figure ES-10: 2007 Sources of HFCs, PFCs, and SF₆ Emissions

15

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

- 17 • Emissions resulting from the substitution of ozone depleting substances (e.g., CFCs) have been increasing from
18 small amounts in 1990 to 108.3 Tg CO₂ Eq. in 2007. Emissions from substitutes for ozone depleting
19 substances are both the largest and the fastest growing source of HFC, PFC, and SF₆ emissions. These
20 emissions have been increasing as phase-outs required under the Montreal Protocol come into effect, especially
21 after 1994 when full market penetration was made for the first generation of new technologies featuring ODS
22 substitutes.
- 23 • HFC emissions from the production of HCFC-22 decreased by 53 percent (19.4 Tg CO₂ Eq.) from 1990
24 through 2007, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per
25 kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23
26 emissions.
- 27 • SF₆ emissions from electric power transmission and distribution systems decreased by 53 percent (14.1 Tg CO₂
28 Eq.) from 1990 to 2007, primarily because of higher purchase prices for SF₆ and efforts by industry to reduce
29 emissions.
- 30 • PFC emissions from aluminum production decreased by 79 percent (14.7 Tg CO₂ Eq.) from 1990 to 2007, due
31 to both industry emission reduction efforts and lower domestic aluminum production.

32 **Overview of Sector Emissions and Trends**

33 In accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*
34 (IPCC/UNEP/OECD/IEA 1997), and the 2003 *UNFCCC Guidelines on Reporting and Review* (UNFCCC 2003),
35 the Inventory of U.S. Greenhouse Gas Emissions and Sinks report is segregated into six sector-specific chapters.
36 Figure ES-11 and Table ES-4 aggregate emissions and sinks by these chapters. Emissions of all gases can be
37 summed from each source category from Intergovernmental Panel on Climate Change (IPCC) guidance. Over the
38 eighteen-year period of 1990 to 2007, total emissions in the Energy, Industrial Processes, and Agriculture sectors
39 climbed by 976.4 Tg CO₂ Eq. (19 percent), 24.9 Tg CO₂ Eq. (8 percent), and 28.9 Tg CO₂ Eq. (8 percent),
40 respectively. Emissions decreased in the Waste and Solvent and Other Product Use sectors by 11.5 Tg CO₂ Eq. (6
41 percent) and less than 0.1 Tg CO₂ Eq. (0.4 percent), respectively. Over the same period, estimates of net C
42 sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 173.30 Tg CO₂ Eq. (20 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 CO₂ Eq.)

Chapter/IPCC Sector	1990	1995	2000	2005	2006	2007
Energy	5,202.1	5,528.7	6,072.1	6,183.7	6,095.0	6,178.5
Industrial Processes	303.5	319.4	330.0	312.8	318.7	328.4
Solvent and Other Product Use	4.4	4.6	4.9	4.4	4.4	4.4
Agriculture	384.2	402.0	399.5	410.8	410.3	413.1
Land Use, Land-Use Change, and Forestry (Emissions)	14.2	15.4	32.7	22.7	37.2	35.3
Waste	177.1	174.7	154.6	160.2	163.0	165.6
Total Emissions	6,085.5	6,444.8	6,993.8	7,094.7	7,028.7	7,125.2
Net CO ₂ Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(883.3)	(819.4)	(766.6)	(1,137.8)	(1,065.6)	(1,077.7)
Net Emissions (Sources and Sinks)	5,202.2	5,625.4	6,227.2	5,956.8	5,963.0	6,047.6

* 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 2007. In 2007, approximately 85 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 15 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 (36 percent and 15 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 86.7 percent of total U.S. greenhouse gas emissions in 2007.

Figure ES-12: 2007 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, cement manufacture, Ammonia Production and urea consumption, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, 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 4.6 percent of U.S. greenhouse gas emissions in 2007.

1 Solvent and Other Product Use

2 The Solvent and Other Product Use chapter contains greenhouse gas emissions that are produced as a by-product of
3 various solvent and other product uses. In the United States, emissions from N₂O from Product Uses, the only
4 source of greenhouse gas emissions from this sector, accounted for less than 0.1 percent of total U.S. anthropogenic
5 greenhouse gas emissions on a carbon equivalent basis in 2007.

6 Agriculture

7 The Agricultural chapter contains anthropogenic emissions from agricultural activities (except fuel combustion,
8 which is addressed in the Energy chapter, and agricultural CO₂ fluxes, which are addressed in the Land Use, Land-
9 Use Change, and Forestry Chapter). Agricultural activities contribute directly to emissions of greenhouse gases
10 through a variety of processes, including the following source categories: enteric fermentation in domestic livestock,
11 livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural
12 residues. CH₄ and N₂O were the primary greenhouse gases emitted by agricultural activities. CH₄ emissions from
13 enteric fermentation and manure management represented about 24 percent and 8 percent of total CH₄ emissions
14 from anthropogenic activities, respectively, in 2007. Agricultural soil management activities such as fertilizer
15 application and other cropping practices were the largest source of U.S. N₂O emissions in 2007, accounting for 67
16 percent. In 2007, emission sources accounted for in the Agricultural chapters were responsible for 6 percent of total
17 U.S. greenhouse gas emissions.

18 Land Use, Land-Use Change, and Forestry

19 The Land Use, Land-Use Change, and Forestry chapter contains emissions of CH₄ and N₂O, and emissions and
20 removals of CO₂ from forest management, other land-use activities, and land-use change. Forest management
21 practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings
22 and food scraps have resulted in a net uptake (sequestration) of C in the United States. Forests (including
23 vegetation, soils, and harvested wood) accounted for approximately 84 percent of total 2007 net CO₂ flux, urban
24 trees accounted for 9 percent, mineral and organic soil carbon stock changes accounted for 6 percent, and landfilled
25 yard trimmings and food scraps accounted for 1 percent of the total net flux in 2007. The net forest sequestration is
26 a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested
27 wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils,
28 mineral and organic soils sequester approximately 70 percent more C than is emitted through these soils, liming, and
29 urea fertilization, combined. The mineral soil C sequestration is largely due to the conversion of cropland to
30 permanent pastures and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the
31 adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and
32 sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due
33 to the long-term accumulation of yard trimming carbon and food scraps in landfills. Land use, land-use change, and
34 forestry activities in 2007 resulted in a net C sequestration of 1,077.7 Tg CO₂ Eq. (Table ES-5). This represents an
35 offset of approximately 17.7 percent of total U.S. CO₂ emissions, or 15.1 percent of total greenhouse gas emissions
36 in 2007. Between 1990 and 2007, total land use, land-use change, and forestry net C flux resulted in a 22.0 percent
37 increase in CO₂ sequestration, primarily due to an increase in the rate of net C accumulation in forest C stocks,
38 particularly in aboveground and belowground tree biomass. Annual C accumulation in landfilled yard trimmings
39 and food scraps slowed over this period, while the rate of annual C accumulation increased in urban trees.

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

Sink Category	1990	1995	2000	2005	2006	2007
Forest Land Remaining Forest Land	(661.1)	(686.6)	(512.6)	(975.7)	(900.3)	(910.1)
Cropland Remaining Cropland	(29.4)	(22.9)	(30.2)	(18.3)	(19.1)	(19.7)
Land Converted to Cropland	2.2	2.9	2.4	5.9	5.9	5.9
Grassland Remaining Grassland	(88.6)	(4.8)	(100.5)	(19.7)	(19.7)	(19.8)
Land Converted to Grassland	(22.3)	(22.5)	(32.0)	(26.7)	(26.7)	(26.7)
Settlements Remaining Settlements	(60.6)	(71.5)	(82.4)	(93.3)	(95.5)	(97.6)
Other (Landfilled Yard Trimmings and Food Scraps)	(23.5)	(13.9)	(11.3)	(10.2)	(10.4)	(9.8)

Total	(883.3)	(819.4)	(766.6)	(1,137.8)	(1,065.6)	(1,077.7)
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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. The application of crushed limestone and dolomite to managed land (i.e., soil liming) and urea fertilization resulted in CO₂ emissions of 8.0 Tg CO₂ Eq. in 2007, and increase of 13 percent relative to 1990. The application of synthetic fertilizers to forest and settlement soils in 2007 resulted in direct N₂O emissions of 1.6 Tg CO₂ Eq. Direct N₂O emissions from fertilizer application increased by approximately 61 percent between 1990 and 2007. Non-CO₂ emissions from forest fires in 2007 resulted in CH₄ emissions of 22.1 Tg CO₂ Eq., and in N₂O emissions of 2.2 Tg CO₂ Eq. CO₂ and N₂O emissions from peatlands totaled 1.0 Tg CO₂ Eq. and just less than 0.01 Tg CO₂ Eq. in 2007, respectively.

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

Source Category	1990	1995	2000	2005	2006	2007
CO₂	8.1	8.1	8.8	8.9	8.8	9.0
Cropland Remaining Cropland:						
Liming of Agricultural Soils	4.7	4.4	4.3	4.3	4.2	4.1
Urea Fertilization	2.4	2.7	3.2	3.5	3.7	4.0
Wetlands Remaining Wetlands:						
Peatlands Remaining Peatlands	1.0	1.0	1.2	1.1	0.9	1.0
CH₄	4.6	5.4	20.4	10.8	24.2	22.1
Forest Land Remaining Forest Land:						
Forest Fires	4.6	5.4	20.4	10.8	24.2	22.1
N₂O	1.5	1.9	3.6	2.9	4.3	4.2
Forest Land Remaining Forest Land:						
Forest Fires	0.5	0.6	2.1	1.1	2.5	2.2
Forest Soils	0.0	0.1	0.3	0.3	0.3	0.3
Wetlands Remaining Wetlands: Peatlands						
Remaining Peatlands	+	+	+	+	+	+
Settlements Remaining Settlements:						
Settlement Soils	1.0	1.2	1.2	1.5	1.5	1.6
Total	14.2	15.4	32.7	22.7	37.2	35.3

+ Less than 0.05 Tg CO₂ Eq.

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

Waste

The Waste chapter contains emissions from waste management activities (except waste incineration, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic CH₄ emissions in the Waste chapter, accounting for 23 percent of total U.S. CH₄ emissions.¹³ Additionally, wastewater treatment accounts for 4 percent of U.S. CH₄ emissions. N₂O emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N₂O emissions from the treatment process itself. Emissions of CH₄ and N₂O from composting grew from 1990 to 2007, and resulted in emissions of 1.7 Tg CO₂ Eq. and 1.8 Tg CO₂ Eq., respectively. Overall, in 2007, emission sources accounted for in the Waste chapter generated 2.3 percent of total U.S. greenhouse gas emissions.

Other Information

¹³ 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.

1 Emissions by Economic Sector

2 Throughout the Inventory of U.S. Greenhouse Gas Emissions and Sinks report, emission estimates are grouped into
 3 six sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes; Solvent Use; Agriculture; Land Use,
 4 Land-Use Change, and Forestry; and Waste. While it is important to use this characterization for consistency with
 5 UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories.
 6 This section reports emissions by the following economic sectors: Residential, Commercial, Industry,
 7 Transportation, Electricity Generation, Agriculture, and U.S. Territories.

8 Table ES-7 summarizes emissions from each of these sectors, and Figure ES-13 shows the trend in emissions by
 9 sector from 1990 to 2007.

10 Figure ES-13: Emissions Allocated to Economic Sectors

11

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

Implied Sectors	1990	1995	2000	2005	2006	2007
Electric Power Industry	1,859.3	1,989.4	2,329.7	2,429.7	2,375.8	2,445.4
Transportation	1,543.6	1,685.2	1,919.7	1,998.9	1,994.4	1,995.2
Industry	1,482.5	1,506.4	1,453.0	1,354.4	1,373.5	1,368.8
Agriculture	428.5	452.9	469.9	479.0	495.1	495.2
Commercial	392.9	401.0	388.2	401.8	392.6	407.6
Residential	344.5	368.8	386.0	370.5	334.9	355.3
U.S. Territories	34.1	41.1	47.3	60.5	62.3	57.7
Total Emissions	6,085.5	6,444.8	6,993.8	7,094.7	7,028.7	7,125.2
Land Use, Land-Use Change, and Forestry (Sinks)	(883.3)	(819.4)	(766.6)	(1,137.8)	(1,065.6)	(1,077.7)
Net Emissions (Sources and Sinks)	5,202.2	5,625.4	6,227.2	5,956.8	5,963.0	6,047.6

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

15

16 Using this categorization, emissions from electricity generation accounted for the largest portion (34 percent) of
 17 U.S. greenhouse gas emissions in 2007. Transportation activities, in aggregate, accounted for the second largest
 18 portion (28 percent). Emissions from industry accounted for 20 percent of U.S. greenhouse gas emissions in 2007.
 19 In contrast to electricity generation and transportation, emissions from industry have in general declined over the
 20 past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e.,
 21 shifts from a manufacturing-based to a service-based economy), fuel switching, and energy efficiency
 22 improvements. The remaining 18 percent of U.S. greenhouse gas emissions were contributed by the residential,
 23 agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for about
 24 5 percent, and primarily consisted of CO₂ emissions from fossil fuel combustion. Activities related to agriculture
 25 accounted for roughly 7 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions
 26 were dominated by N₂O emissions from agricultural soil management and CH₄ emissions from enteric fermentation,
 27 rather than CO₂ from fossil fuel combustion. The commercial sector accounted for about 6 percent of emissions,
 28 while U.S. territories accounted for approximately 1 percent.

29 CO₂ was also emitted and sequestered by a variety of activities related to forest management practices, tree planting
 30 in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

31 Electricity is ultimately consumed in the economic sectors described above. Table ES-8 presents greenhouse gas
 32 emissions from economic sectors with emissions related to electricity generation distributed into end-use categories
 33 (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is
 34 consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories
 35 assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and

1 agriculture economic sectors according to retail sales of electricity.¹⁴ These source categories include CO₂ from
 2 fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO₂ and N₂O from waste
 3 incineration, CH₄ and N₂O from stationary sources, and SF₆ from electrical transmission and distribution systems.

4 When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S.
 5 greenhouse gas emissions (29 percent) in 2007. Emissions from the residential and commercial sectors also
 6 increase substantially when emissions from electricity are included, due to their relatively large share of electricity
 7 consumption (e.g., lighting, appliances, etc.). Transportation activities remain the second largest contributor to total
 8 U.S. emissions (28 percent). In all sectors except agriculture, CO₂ accounts for more than 80 percent of greenhouse
 9 gas emissions, primarily from the combustion of fossil fuels. Figure ES-14 shows the trend in these emissions by
 10 sector from 1990 to 2007.

11 Table ES-8: U.S. Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed
 12 (Tg CO₂ Eq.)

Implied Sectors	1990	1995	2000	2005	2006	2007
Industry	2,153.2	2,201.9	2,221.0	2,070.7	2,067.3	2,063.7
Transportation	1,546.7	1,688.3	1,923.2	2,003.6	1,999.0	2,000.1
Commercial	942.2	1,000.3	1,140.1	1,214.7	1,201.6	1,251.3
Residential	950.1	1,024.3	1,159.3	1,237.1	1,176.2	1,229.9
Agriculture	459.2	488.9	502.9	508.0	522.3	522.6
U.S. Territories	34.1	41.1	47.3	60.5	62.3	57.7
Total Emissions	6,085.5	6,444.8	6,993.8	7,094.7	7,028.7	7,125.2
Land Use, Land-Use Change, and Forestry (Sinks)	(883.3)	(819.4)	(766.6)	(1,137.8)	(1,065.6)	(1,077.7)
Net Emissions (Sources and Sinks)	5,202.2	5,625.4	6,227.2	5,956.8	5,963.0	6,047.6

13 See Table 2-14 for more detailed data.

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

18 [BEGIN BOX]

19 Box ES-2: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

21 Total emissions can be compared to other economic and social indices to highlight changes over time. These
 22 comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are
 23 the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related
 24 emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the
 25 electric power industry—utilities and nonutilities combined—was the largest source of U.S. greenhouse gas
 26 emissions in 2007; (4) emissions per unit of total gross domestic product as a measure of national economic activity;
 27 or (5) emissions per capita.

¹⁴ 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.

1 Table ES-9 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a
 2 baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.9 percent
 3 since 1990. This rate is slightly slower than that for total energy or fossil fuel consumption and much slower than
 4 that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have
 5 also grown slightly slower than national population since 1990 (see Figure ES-15).

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

Variable	1990	1995	2000	2005	2006	2007	Growth Rate ^a
GDP ^b	100	113	138	155	159	162	2.9%
Electricity Consumption ^c	100	112	127	134	135	137	1.9%
Fossil Fuel Consumption ^c	100	107	117	119	117	119	1.1%
Energy Consumption ^c	100	108	117	119	118	120	1.1%
Population ^d	100	107	113	118	119	120	1.1%
Greenhouse Gas Emissions ^e	100	106	115	117	115	117	0.9%

7 ^a Average annual growth rate

8 ^b Gross Domestic Product in chained 2000 dollars (BEA 2008)

9 ^c Energy content-weighted values (EIA 2008a)

10 ^d U.S. Census Bureau (2008)

11 ^e GWP-weighted values

12

13 Figure ES-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
 14 Source: BEA (2008), U.S. Census Bureau (2008), and emission estimates in this report.

15

16 [END BOX]

17

18 Indirect Greenhouse Gases (CO, NO_x, NMVOCs, and SO₂)—To Be Updated

19 The reporting requirements of the UNFCCC¹⁵ request that information be provided on indirect greenhouse gases,
 20 which include CO, NO_x, NMVOCs, and SO₂. These gases do not have a direct global warming effect, but indirectly
 21 affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric
 22 ozone, or, in the case of SO₂, by affecting the absorptive characteristics of the atmosphere. Additionally, some of
 23 these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse
 24 gases.

25 Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO₂ (EPA
 26 2008),¹⁶ which are regulated under the Clean Air Act. Table ES-10 shows that fuel combustion accounts for the
 27 majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of
 28 chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO,
 29 NO_x, and NMVOCs.

30 Table ES-10: Emissions of NO_x, CO, NMVOCs, and SO₂ (Gg)

Gas/Activity	1990	1995	2000	2005	2006	2007
NO _x	21,450	21,070	19,004	15,612	14,701	14,250

¹⁵ See <<http://unfccc.int/resource/docs/cop8/08.pdf>>.

¹⁶ NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2008).

Mobile Fossil Fuel Combustion	10,920	10,622	10,310	8,757	8,271	7,831
Stationary Fossil Fuel Combustion	9,689	9,619	7,802	5,857	5,445	5,445
Industrial Processes	591	607	626	534	527	520
Oil and Gas Activities	139	100	111	321	316	314
Waste Incineration	82	88	114	98	98	97
Agricultural Burning	28	29	35	39	38	37
Solvent Use	1	3	3	5	5	5
Waste	0	1	2	2	2	2
CO	130,461	109,032	92,776	71,672	67,453	63,875
Mobile Fossil Fuel Combustion	119,360	97,630	83,559	62,519	58,322	54,678
Stationary Fossil Fuel Combustion	5,000	5,383	4,340	4,778	4,792	4,792
Industrial Processes	4,125	3,959	2,216	1,744	1,743	1,743
Waste Incineration	978	1,073	1,670	1,439	1,438	1,438
Agricultural Burning	691	663	792	860	825	892
Oil and Gas Activities	302	316	146	324	323	323
Waste	1	2	8	7	7	7
Solvent Use	5	5	45	2	2	2
NMVOCs	20,930	19,520	15,227	14,562	14,129	13,747
Mobile Fossil Fuel Combustion	10,932	8,745	7,229	6,292	5,954	5,672
Solvent Use	5,216	5,609	4,384	3,881	3,867	3,855
Industrial Processes	2,422	2,642	1,773	2,035	1,950	1,878
Stationary Fossil Fuel Combustion	912	973	1,077	1,450	1,470	1,470
Oil and Gas Activities	554	582	388	545	535	526
Waste Incineration	222	237	257	243	239	234
Waste	673	731	119	115	113	111
Agricultural Burning	NA	NA	NA	NA	NA	NA
SO₂	20,935	16,891	14,830	13,348	12,259	11,725
Stationary Fossil Fuel Combustion	18,407	14,724	12,849	11,641	10,650	10,211
Industrial Processes	1,307	1,117	1,031	852	845	839
Mobile Fossil Fuel Combustion	793	672	632	600	520	442
Oil and Gas Activities	390	335	287	233	221	210
Waste Incineration	38	42	29	22	22	22
Waste	0	1	1	1	1	1
Solvent Use	0	1	1	0	0	0
Agricultural Burning	NA	NA	NA	NA	NA	NA

1 Source: (EPA 2008, disaggregated based on EPA 2003) except for estimates from field burning of agricultural residues.

2 NA (Not Available)

3 Note: Totals may not sum due to independent rounding.

4

5 Key Categories

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

¹⁷ See Chapter 7 “Methodological Choice and Recalculation” in IPCC (2000).

<<http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm>>

1 Figure ES-16 presents 2007 emission estimates for the key categories as defined by a level analysis (i.e., the
2 contribution of each source or sink category to the total inventory level). The UNFCCC reporting guidelines
3 request that key category analyses be reported at an appropriate level of disaggregation, which may lead to source
4 and sink category names which differ from those used elsewhere in the inventory report. For more information
5 regarding key categories, see section 1.5 and Annex 1 of the inventory report.

6

7 Figure ES-16: 2007 Key Categories

8

9 Quality Assurance and Quality Control (QA/QC)

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

15 Uncertainty Analysis of Emission Estimates

16 While the current U.S. emissions inventory provides a solid foundation for the development of a more detailed and
17 comprehensive national inventory, there are uncertainties associated with the emission estimates. Some of the
18 current estimates, such as those for CO₂ emissions from energy-related activities and cement processing, are
19 considered to have low uncertainties. For some other categories of emissions, however, a lack of data or an
20 incomplete understanding of how emissions are generated increases the uncertainty associated with the estimates
21 presented. Acquiring a better understanding of the uncertainty associated with inventory estimates is an important
22 step in helping to prioritize future work and improve the overall quality of the Inventory. Recognizing the benefit
23 of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the IPCC
24 *Good Practice Guidance* (IPCC 2000) and require that countries provide single estimates of uncertainty for source
25 and sink categories.

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

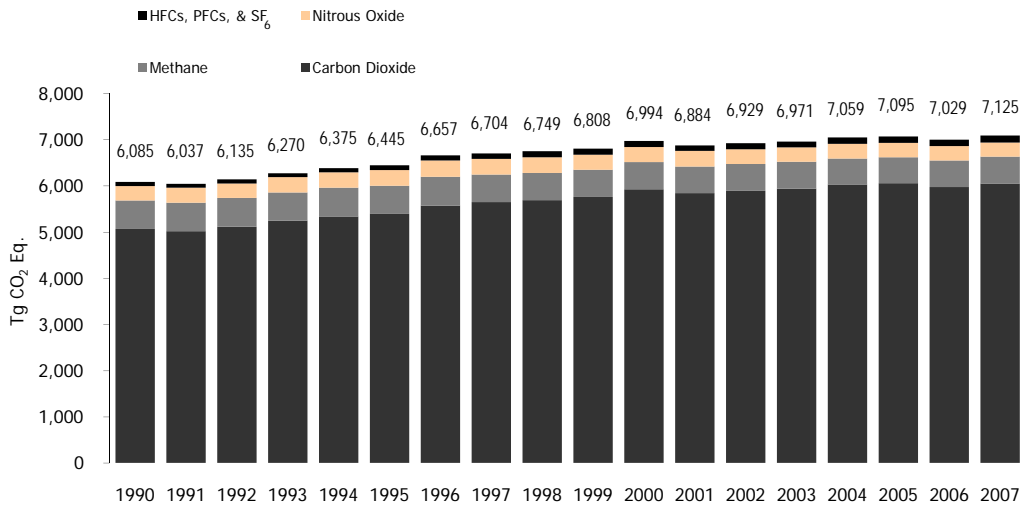


Figure ES-1: U.S. Greenhouse Gas Emissions by Gas

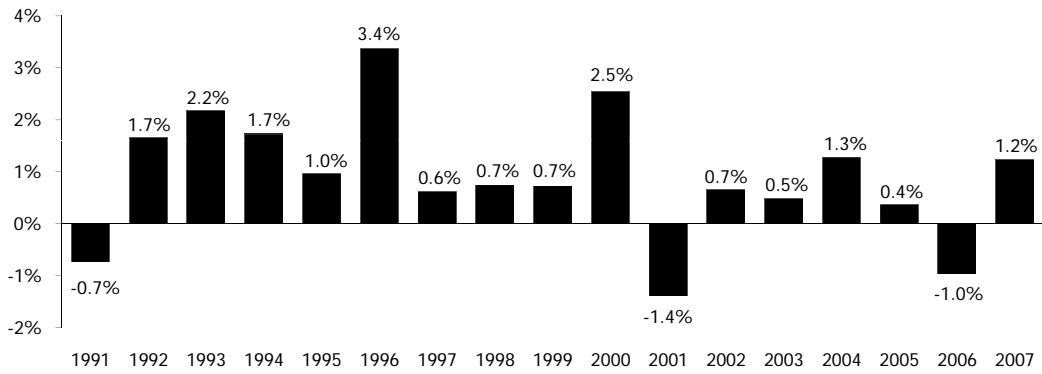


Figure ES-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

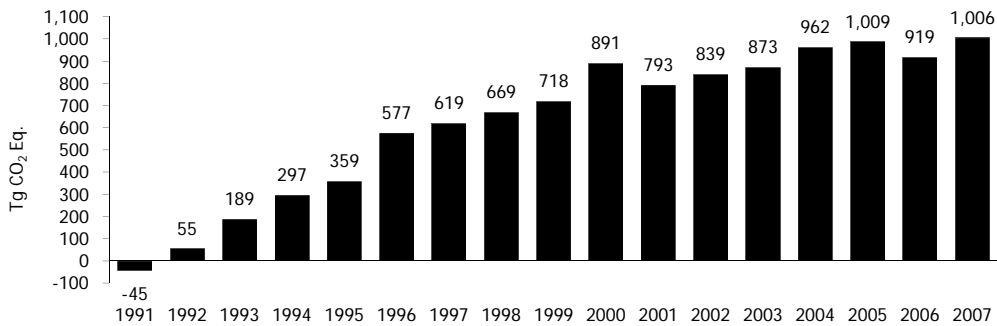


Figure ES-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990

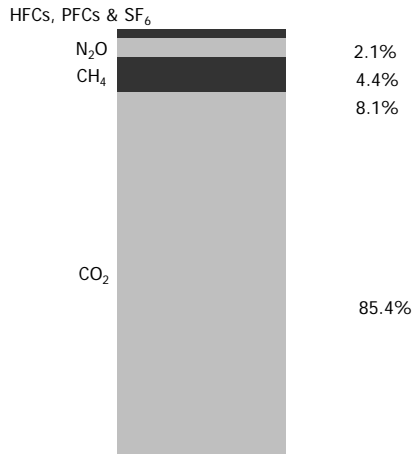


Figure ES-4: 2007 Greenhouse Gas Emissions by Gas (percents based on Tg CO₂ Eq.)

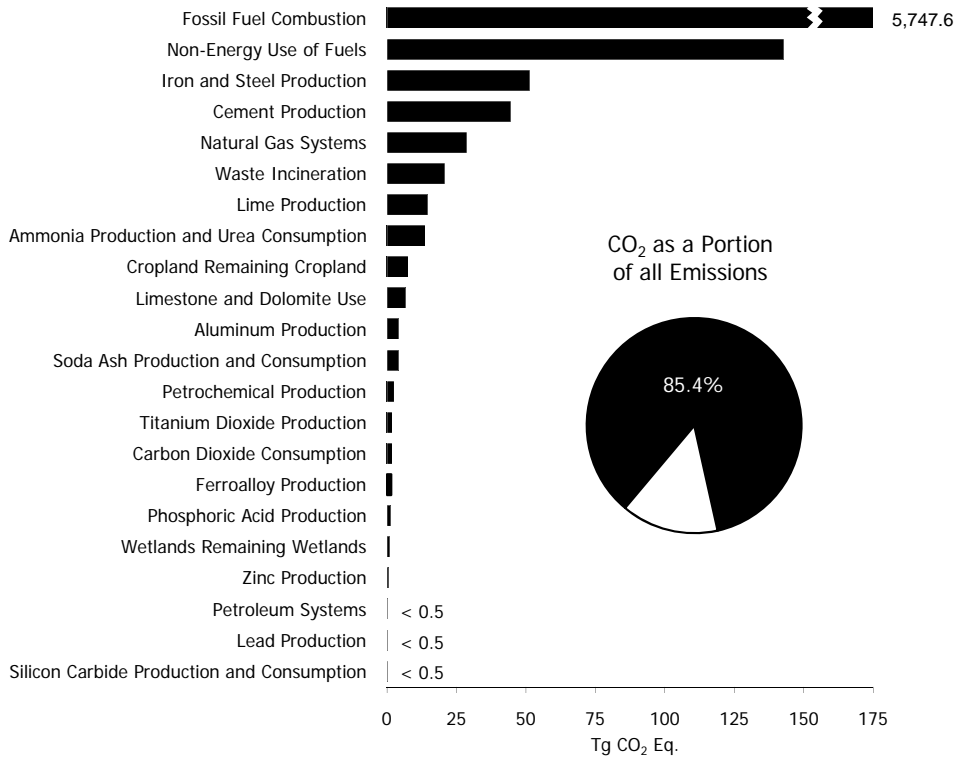


Figure ES-5: 2007 Sources of CO₂ Emissions

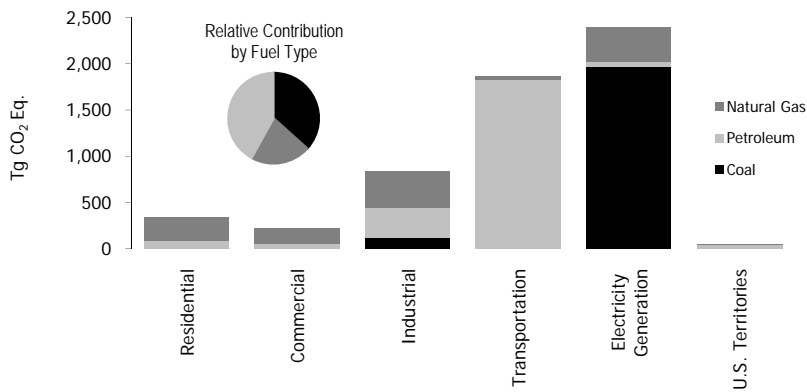


Figure ES-6: 2007 CO₂ Emissions from Fossil Fuel Combustion by Sector and Fuel Type
 Note: Electricity generation also includes emissions of less than 0.5 Tg CO₂ Eq. from geothermal-based electricity generation.

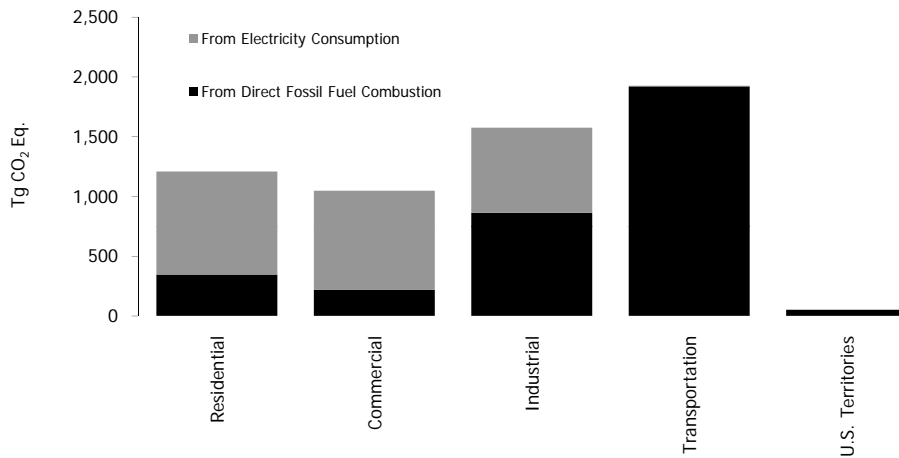


Figure ES-7: 2007 End-Use Sector Emissions of CO₂, CH₄, and N₂O from Fossil Fuel Combustion

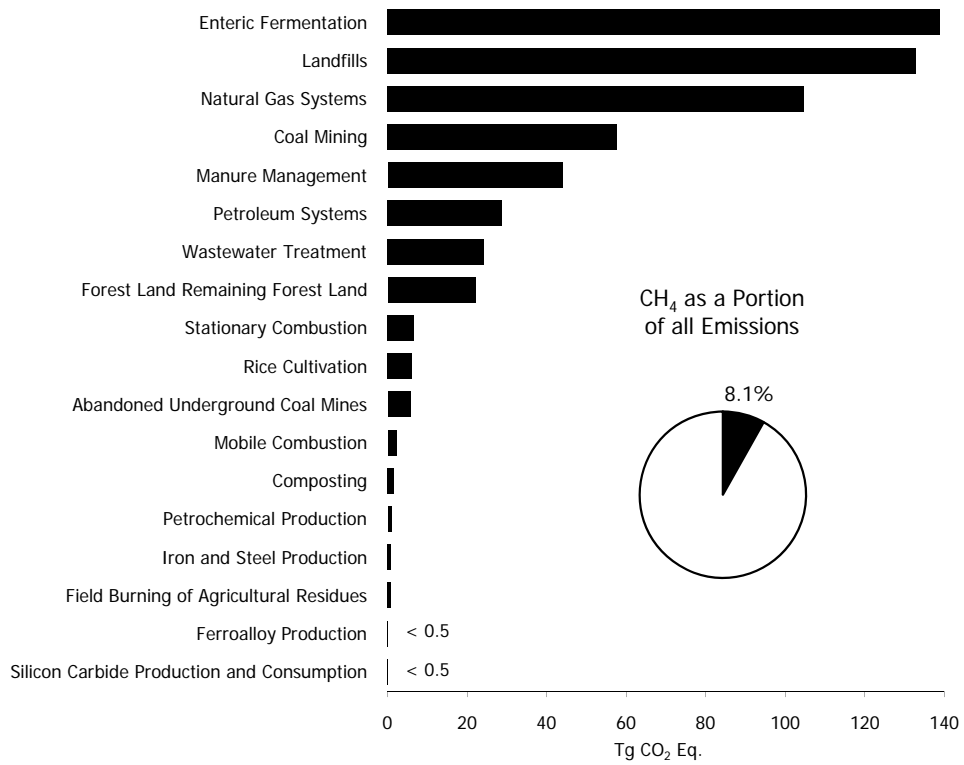


Figure ES-8: 2007 Sources of CH₄ Emissions

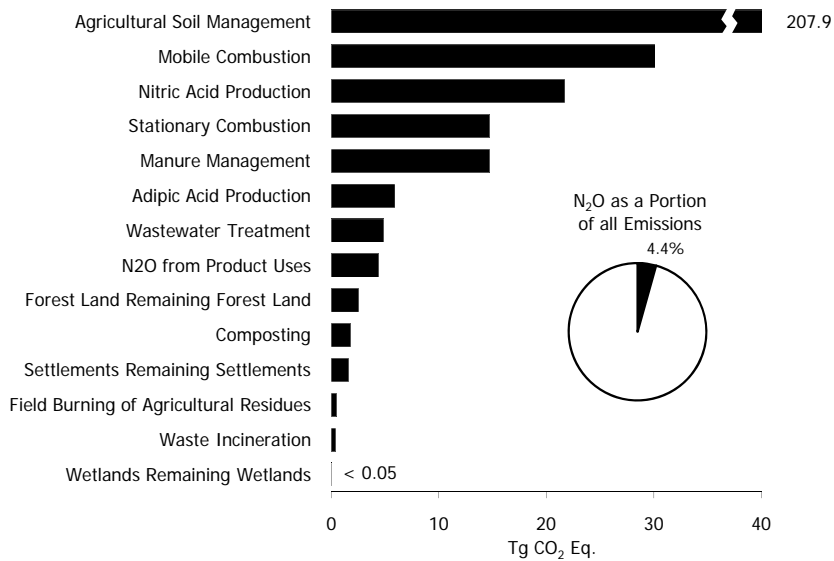


Figure ES-9: 2007 Sources of N₂O Emissions

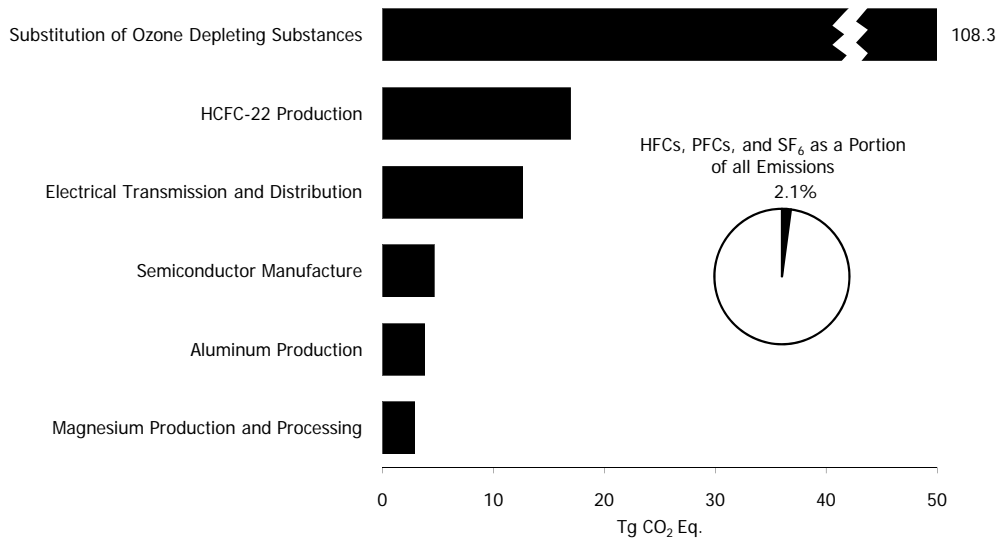
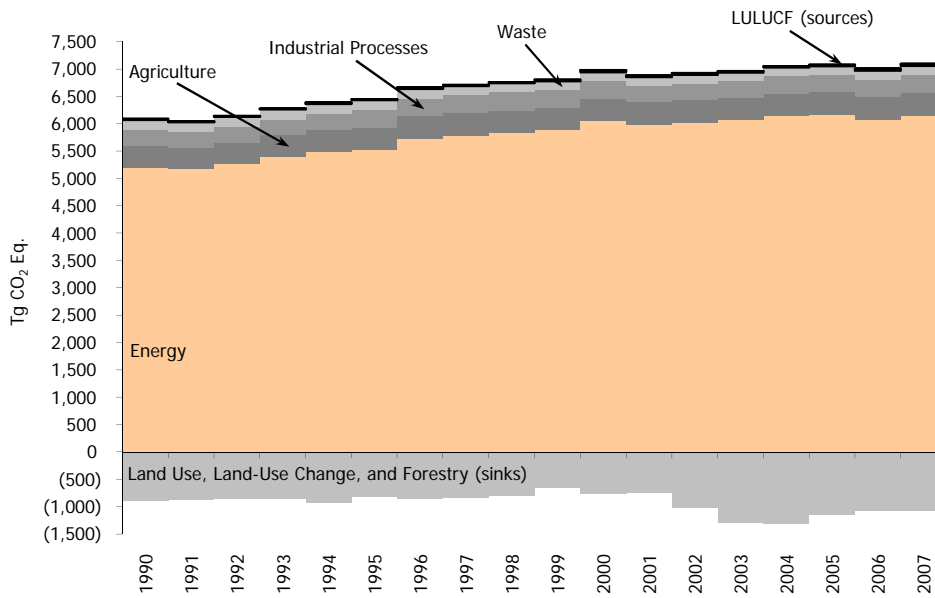


Figure ES-10: 2007 Sources of HFCs, PFCs, and SF₆ Emissions



Note: Relatively smaller amounts of GWP-weighted emissions are also emitted from the Solvent and Other Product Use sector.

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

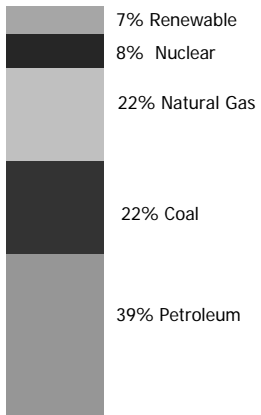


Figure ES-12: 2007 U.S. Energy Consumption by Energy Source

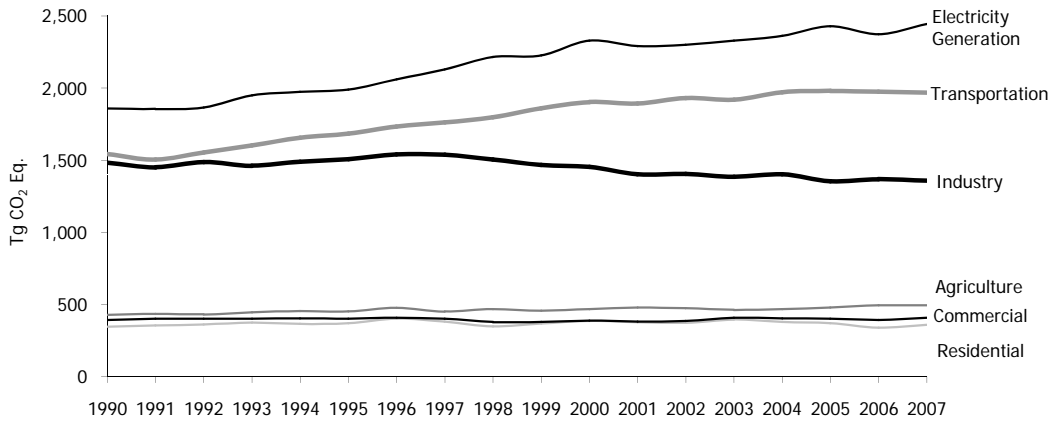


Figure ES-13: Emissions Allocated to Economic Sectors
 Note: Does not include U.S. Territories.

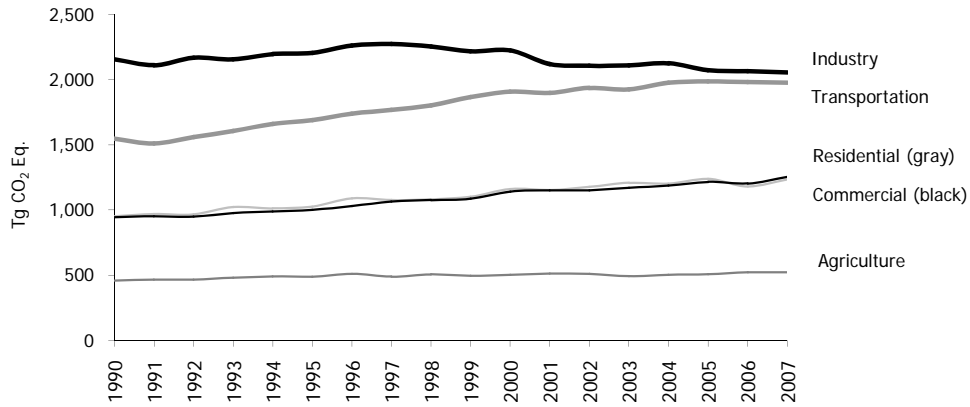


Figure ES-14: Emissions with Electricity Distributed to Economic Sectors
 Note: Does not include U.S. Territories.

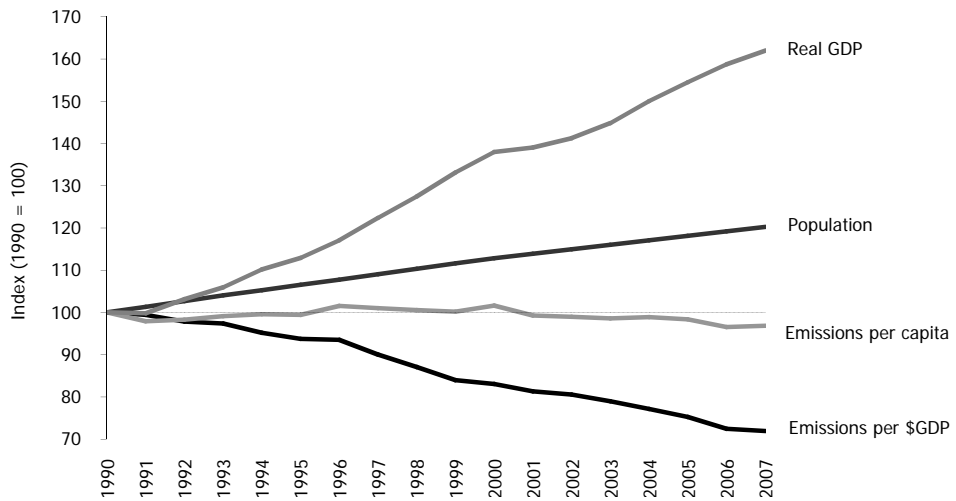


Figure ES-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product

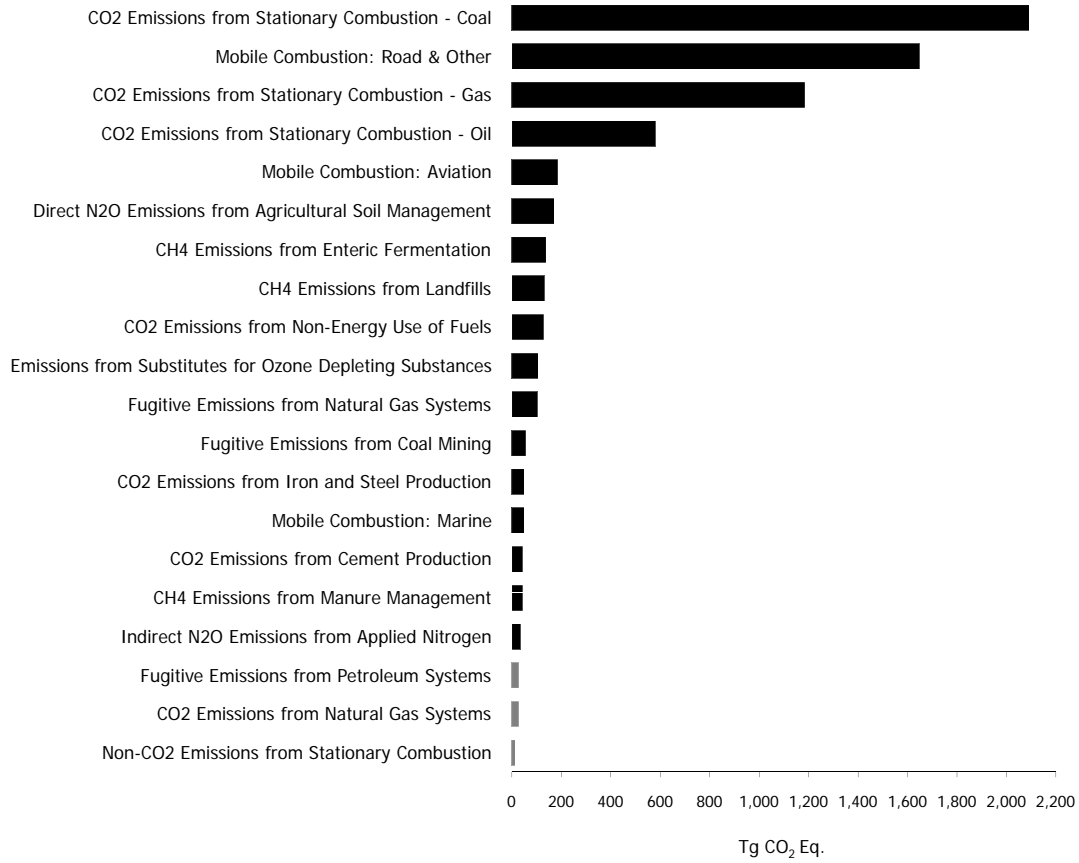


Figure ES-16: 2007 Key Categories

Notes: For a complete discussion of the key source analysis, see Annex 1.

Black bars indicate a Tier 1 level assessment key category.

Gray bars indicate a Tier 2 level assessment key category.