2. Trends in Greenhouse Gas Emissions

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

In 2015, total gross U.S. greenhouse gas emissions were 6,586.7 MMT, or million metric tons, carbon dioxide (CO_2) 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 CO_2 Eq.). The decrease in total greenhouse gas emissions between 2014 and 2015 was driven in large part by a decrease in CO_2 emissions from fossil fuel combustion. The decrease in CO_2 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. Since 1990, U.S. emissions have increased at an average annual rate of 0.2 percent. Figure 2-1 through Figure 2-3 illustrate the overall trend in total U.S. emissions by gas, annual changes, and absolute changes since 1990. Overall, net emissions in 2015 were 11.5 percent below 2005 levels as shown in Table 2-1.

Figure 2-1: Gross U.S. Greenhouse Gas Emissions by Gas (MMT CO_2 Eq.)

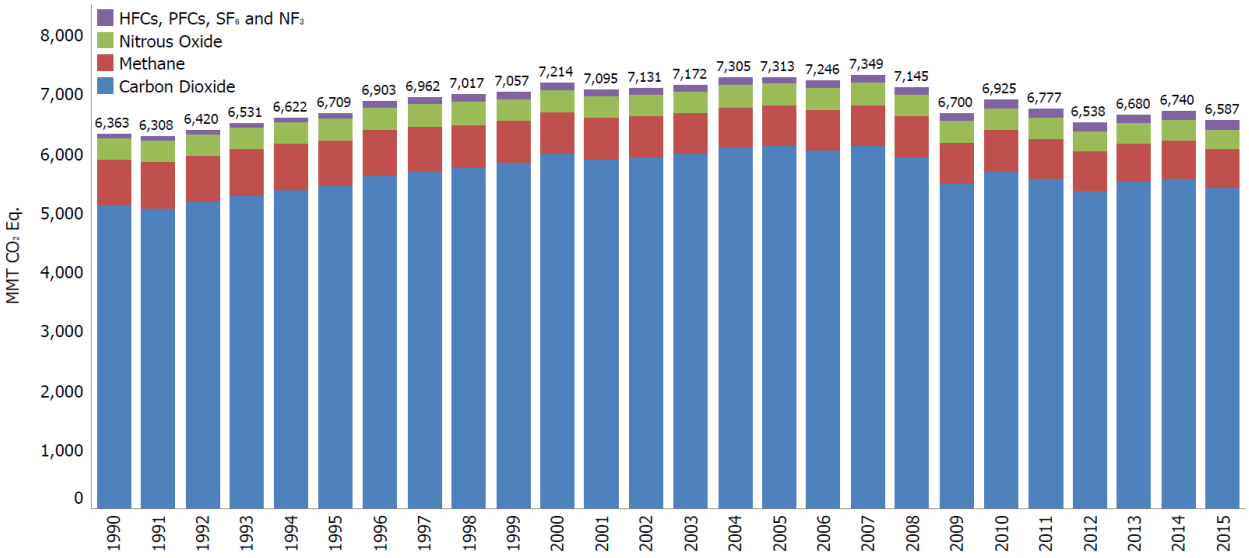


Figure 2-2: Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year

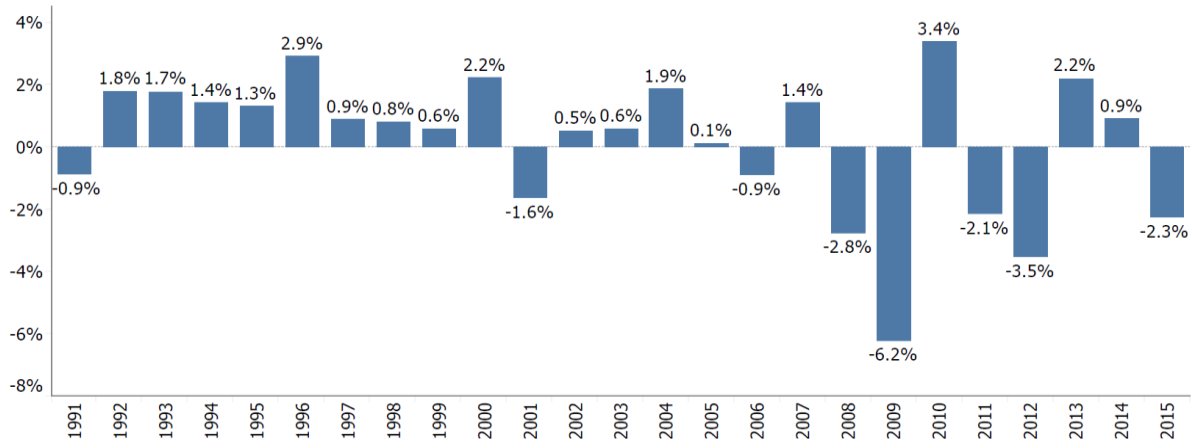
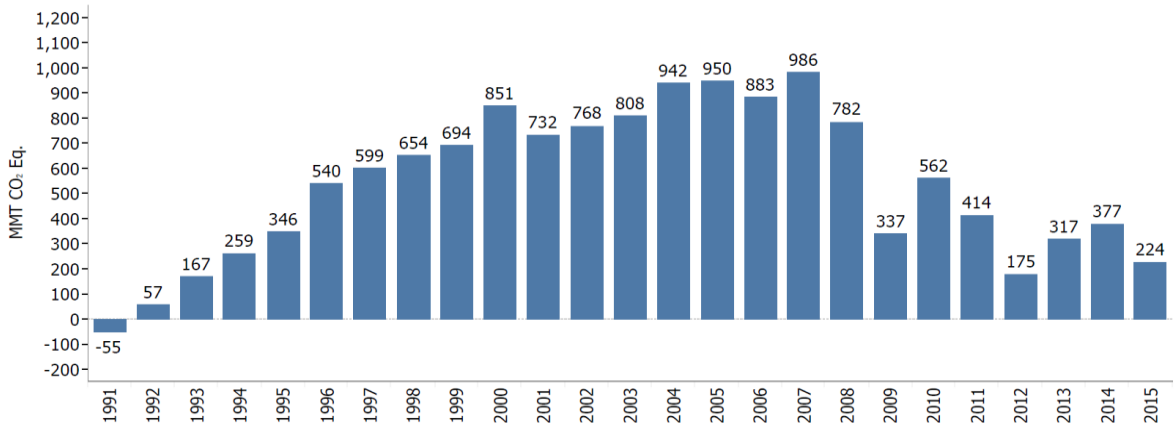


Figure 2-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)



Overall, from 1990 to 2015, total emissions of CO_2 increased by 288.4 MMT CO_2 Eq. (5.6 percent), while total emissions of methane (CH_4) decreased by 125.1 MMT CO_2 Eq. (16.0 percent), and total emissions of nitrous oxide (N_2O) decreased by 24.7 MMT CO_2 Eq. (6.9 percent). During the same period, aggregate weighted emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) rose by 85.0 MMT CO_2 Eq. (85.3 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, SF_6, and NF_3 are significant because many of them have extremely high global warming potentials (GWPs), and, in the cases of PFCs, SF_6, and NF_3, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon (C) sequestration in managed forests, trees in urban areas, agricultural soils, landfilled yard trimmings, and coastal wetlands. These were estimated to offset 11.8 percent of total emissions in 2015.

As the largest contributor to U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 77 percent of GWP-weighted emissions for the entire time series since 1990. Emissions from this source category grew by 6.5 percent (309.4 MMT CO_2 Eq.) from 1990 to 2015 and were responsible for most of the increase in national emissions during this period. In addition, CO_2 emissions from fossil fuel combustion decreased

from 2005 levels by 697.2 MMT CO_2 Eq., a decrease of approximately 12.1 percent between 2005 and 2015. From 2014 to 2015, these emissions decreased by 2.9 percent (152.5 MMT CO_2 Eq.). Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations and market trends, technological changes, energy fuel choices, and seasonal temperatures. On an annual basis, 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. For example, coal consumption for electricity generation is influenced by a number of factors including the relative price of coal and alternative sources, the ability to switch fuels, and longer terms trends in coal markets. Likewise, warmer winters will lead to a decrease in heating degree days and result in a decreased demand for heating fuel and electricity for heat in the residential and commercial sector, which leads to a decrease in emissions from reduced fuel use.

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its C intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas (see Table A-39 in Annex 2.1 for more detail on the C Content Coefficient of different fossil fuels).

A brief discussion of the year to year variability in fuel combustion emissions is provided below, beginning with 2011.

Recent trends in CO_2 emissions from fossil fuel combustion show a 3.9 percent decrease from 2011 to 2012, then a 2.6 percent and a 0.9 percent increase from 2012 to 2013 and 2013 to 2014, respectively, and a 2.9 percent decrease from 2014 to 2015. Total electricity generation remained relatively flat over that time period but emission trends generally mirror the trends in the amount of coal used to generate electricity. The consumption of coal used to generate electricity decreased by roughly 12 percent from 2011 to 2012, increased by 4 percent from 2012 to 2013, stayed relatively flat from 2013 to 2014, and decreased by 14 percent from 2014 to 2015. The overall CO_2 emission trends from fossil fuel combustion also follow closely changes in heating degree days over that time period. Heating degree days decreased by 13 percent from 2011 to 2012, increased by 18 percent from 2012 to 2013, increased by 2 percent from 2013 to 2014, and decreased by 10 percent from 2014 to 2015. The overall CO_2 emission trends from fossil fuel combustion also generally follow changes in overall petroleum use and emissions. Carbon dioxide emissions from petroleum decreased by 2.0 percent from 2011 to 2012, increased by 1.6 percent from 2012 to 2013, increased by 0.8 percent from 2013 to 2014, and increased by 1.7 percent from 2014 to 2015. The increase in petroleum CO_2 emissions from 2014 to 2015 somewhat offset emission reductions from decreased coal use in the electricity sector from 2014 to 2015.

Table 2-1 summarizes emissions and sinks from all U.S. anthropogenic sources in weighted units of MMT CO_2 Eq., while unweighted gas emissions and sinks in kilotons (kt) are provided in Table 2-2.

Table 2-1: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**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
Electricity Generation	*1,820.8*	*2,400.9*	*2,157.7*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*
Transportation[a]	*1,493.8*	*1,887.0*	*1,707.6*	*1,696.8*	*1,713.0*	*1,742.8*	*1,736.4*
Industrial[a]	*842.5*	*828.0*	*775.0*	*782.9*	*812.2*	*806.1*	*805.5*
Residential	*338.3*	*357.8*	*325.5*	*282.5*	*329.7*	*345.4*	*319.6*
Commercial[a]	*217.4*	*223.5*	*220.4*	*196.7*	*221.0*	*228.7*	*246.2*
U.S. Territories	*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	+	+	+	+	+	+	+
Wood Biomass, Ethanol, and Biodiesel Consumption[b]	*219.4*	*230.7*	*276.4*	*276.2*	*299.8*	*307.1*	*291.7*
International Bunker Fuels[c]	*103.5*	*113.1*	*111.7*	*105.8*	*99.8*	*103.2*	*110.8*
CH_4	**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	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**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_2O 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
International Bunker Fuels[c]	*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	+	+	+	+	+	+
SF_6	**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
NF_3	**+**	**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. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

+ Does not exceed 0.05 MMT CO_2 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, Ethanol, and Biodiesel 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 LULUCF.

[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 CH_4 and N_2O emissions reported for *Peatlands Remaining Peatlands*, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands*; and N_2O 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 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

[g] The LULUCF Sector Net Total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Table 2-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (kt)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**5,123,043**	**6,131,833**	**5,569,516**	**5,362,095**	**5,514,018**	**5,565,495**	**5,411,409**
Fossil Fuel Combustion	4,740,343	5,746,942	5,227,061	5,024,643	5,156,523	5,202,300	5,049,763
Electricity Generation	*1,820,818*	*2,400,874*	*2,157,688*	*2,022,181*	*2,038,122*	*2,038,018*	*1,900,673*
Transportation[a]	*1,493,758*	*1,887,033*	*1,707,631*	*1,696,752*	*1,713,002*	*1,742,814*	*1,736,383*

Industrial[a]	*842,473*	*827,999*	*774,951*	*782,929*	*812,228*	*806,075*	*805,496*
Residential	*338,347*	*357,834*	*325,537*	*282,540*	*329,674*	*345,362*	*319,591*
Commercial[a]	*217,393*	*223,480*	*220,381*	*196,714*	*221,030*	*228,666*	*246,241*
U.S. Territories	*27,555*	*49,723*	*40,874*	*43,527*	*42,467*	*41,365*	*41,380*
Non-Energy Use of Fuels	117,585	138,913	109,756	106,750	123,645	118,995	125,526
Iron and Steel Production & Metallurgical Coke Production	101,487	68,047	61,108	55,449	53,348	58,629	48,876
Natural Gas Systems	37,732	30,076	35,662	35,203	38,457	42,351	42,351
Cement Production	33,484	46,194	32,208	35,270	36,369	39,439	39,907
Petrochemical Production	21,326	26,972	26,338	26,501	26,395	26,496	28,062
Lime Production	11,700	14,552	13,982	13,785	14,028	14,210	13,342
Other Process Uses of Carbonates	4,907	6,339	9,335	8,022	10,414	11,811	11,236
Ammonia Production	13,047	9,196	9,292	9,377	9,962	9,619	10,799
Incineration of Waste	7,950	12,469	10,564	10,379	10,398	10,608	10,676
Urea Fertilization	2,417	3,504	4,097	4,267	4,504	4,781	5,032
Carbon Dioxide Consumption	1,472	1,375	4,083	4,019	4,188	4,471	4,296
Liming	4,667	4,349	3,873	5,978	3,907	3,609	3,810
Petroleum Systems	3,553	3,927	4,192	3,876	3,693	3,567	3,567
Soda Ash Production and Consumption	2,822	2,960	2,712	2,763	2,804	2,827	2,789
Aluminum Production	6,831	4,142	3,292	3,439	3,255	2,833	2,767
Ferroalloy Production	2,152	1,392	1,735	1,903	1,785	1,914	1,960
Titanium Dioxide Production	1,195	1,755	1,729	1,528	1,715	1,688	1,635
Glass Production	1,535	1,928	1,299	1,248	1,317	1,336	1,299
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	4,030	4,407	4,014	1,380	1,128
Phosphoric Acid Production	1,529	1,342	1,171	1,118	1,149	1,038	999
Zinc Production	632	1,030	1,286	1,486	1,429	956	933
Lead Production	516	553	538	527	546	459	473
Silicon Carbide Production and Consumption	375	219	170	158	169	173	180
Magnesium Production and Processing	1	3	3	2	2	2	3
Wood Biomass, Ethanol, and Biodiesel Consumption[b]	*219,413*	*230,700*	*276,413*	*276,201*	*299,785*	*307,079*	*291,735*
International Bunker Fuels[c]	*103,463*	*113,139*	*111,660*	*105,805*	*99,763*	*103,201*	*110,751*
CH_4	**31,232**	**27,238**	**26,884**	**26,643**	**26,351**	**26,366**	**26,229**
Enteric Fermentation	6,566	6,755	6,757	6,670	6,619	6,567	6,661
Natural Gas Systems	7,762	6,387	6,180	6,247	6,368	6,501	6,497
Landfills	7,182	5,372	4,760	4,834	4,669	4,663	4,628
Manure Management	1,486	2,254	2,519	2,625	2,530	2,514	2,651
Coal Mining	3,860	2,565	2,849	2,658	2,584	2,593	2,436
Petroleum Systems	2,218	1,840	1,922	1,858	1,778	1,721	1,595
Wastewater Treatment	627	639	613	604	597	592	591
Rice Cultivation	641	667	564	453	454	456	449
Stationary Combustion	339	296	283	265	320	323	280
Abandoned Underground Coal Mines	288	264	257	249	249	253	256
Composting	15	75	75	77	81	84	84
Mobile Combustion[a]	226	113	91	87	85	82	80
Field Burning of Agricultural Residues	9	8	11	11	11	11	11
Petrochemical Production	9	3	2	3	3	5	7
Ferroalloy Production	1	+	+	1	+	1	1
Silicon Carbide Production and Consumption	1	+	+	+	+	+	+

Iron and Steel Production & Metallurgical Coke Production	1	1	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*7*	*5*	*5*	*4*	*3*	*3*	*3*
N_2O	**1,207**	**1,214**	**1,222**	**1,143**	**1,126**	**1,126**	**1,124**
Agricultural Soil Management	861	872	906	853	841	839	843
Stationary Combustion	40	68	71	72	77	78	78
Manure Management	47	55	58	59	59	59	59
Mobile Combustion[a]	138	120	77	68	62	56	51
Nitric Acid Production	41	38	37	35	36	37	39
Wastewater Treatment	11	15	16	16	16	16	17
Adipic Acid Production	51	24	34	19	13	18	14
N_2O from Product Uses	14	14	14	14	14	14	14
Composting	1	6	6	6	6	6	6
Incineration of Waste	2	1	1	1	1	1	1
Semiconductor Manufacture	+	+	1	1	1	1	1
Field Burning of Agricultural Residues	+	+	+	+	+	+	+
International Bunker Fuels[c]	*3*	*3*	*3*	*3*	*3*	*3*	*3*
HFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances[d]	M	M	M	M	M	M	M
HCFC-22 Production	3	1	1	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+
Magnesium Production and Processing	0	0	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Semiconductor Manufacture	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M
Substitution of Ozone Depleting Substances	0	+	+	+	+	+	+
SF_6	**1**	**1**	**+**	**+**	**+**	**+**	**+**
Electrical Transmission and Distribution	1	+	+	+	+	+	+
Magnesium Production and Processing	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+
NF_3	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+

+ Does not exceed 0.5 kt.

M - Mixture of multiple gases

[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, Ethanol, and Biodiesel 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 LULUCF.

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

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

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

Emissions of all gases can be summed from each source category into a set of five sectors defined by the Intergovernmental Panel on Climate Change (IPCC). Figure 2-4 and Table 2-3 illustrate that over the twenty-six year period of 1990 to 2015, total emissions in the Energy, Industrial Processes and Product Use, and Agriculture sectors grew by 221.0 MMT CO_2 Eq. (4.1 percent), 35.5 MMT CO_2 Eq. (10.4 percent), and 27.0 MMT CO_2 Eq. (5.5 percent), respectively. Emissions from the Waste sector decreased by 59.9 MMT CO_2 Eq. (30.1 percent). Over the same period, estimates of net C sequestration for the Land Use, Land-Use Change, and Forestry sector (magnitude

of emissions plus CO_2 removals from all LULUCF categories) increased by 60.7 MMT CO_2 Eq. (7.4 percent decrease in net C sequestration).

Figure 2-4: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

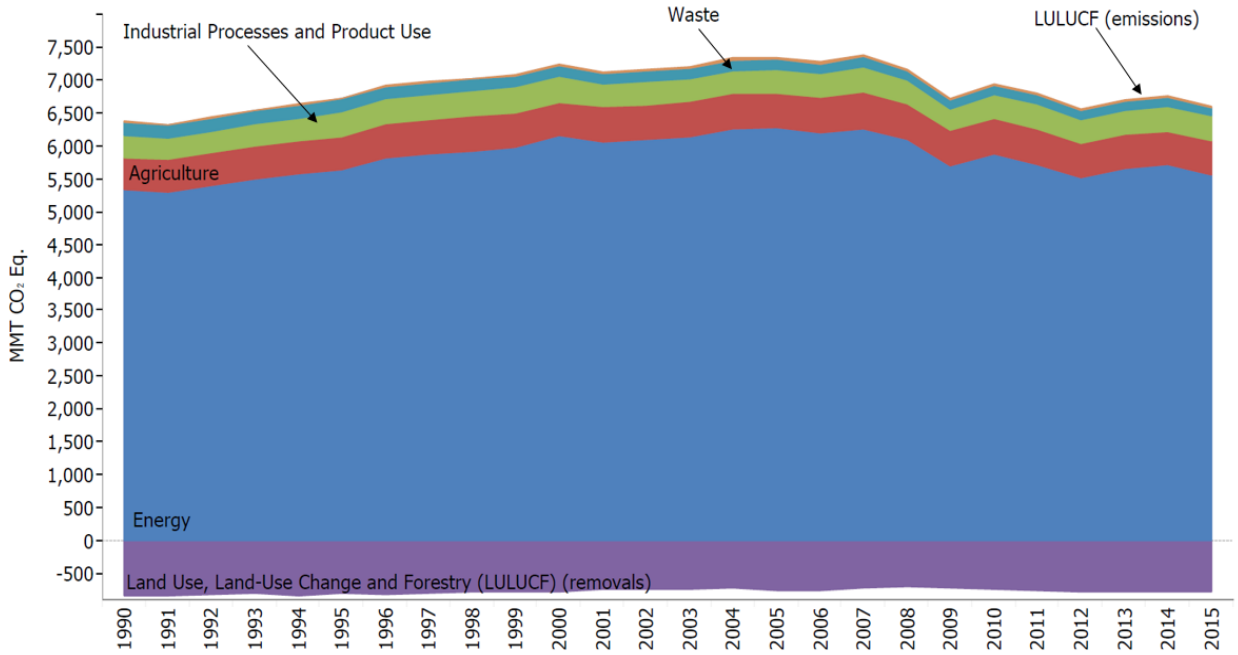


Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

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_2O 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 Emission (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] Net emissions with LULUCF.

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

Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2015. Emissions from fossil fuel combustion comprise the vast majority of energy-related emissions, with CO_2 being the primary gas emitted (see Figure 2-5). Due to their relative importance, fossil fuel combustion-related CO_2 emissions are considered in detail in the Energy chapter (see Figure 2-6). 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. A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (42 percent and 12 percent of total U.S. emissions of each gas, respectively). Table 2-4 presents greenhouse gas emissions from the Energy chapter, by source and gas.

Figure 2-5: 2015 Energy Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

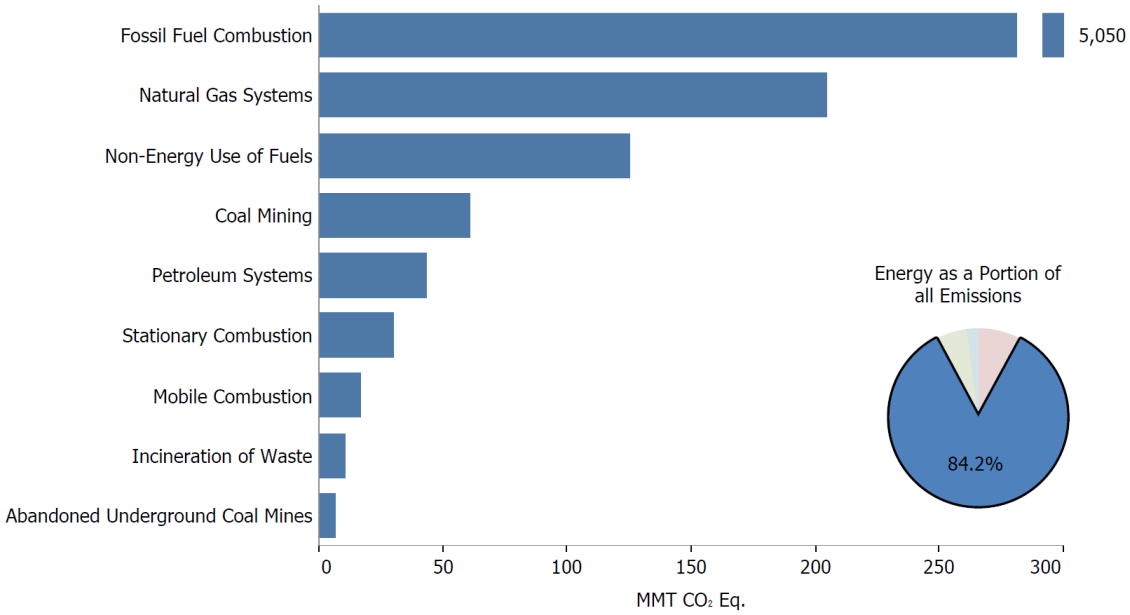


Figure 2-6: 2015 U.S. Fossil Carbon Flows (MMT CO_2 Eq.)

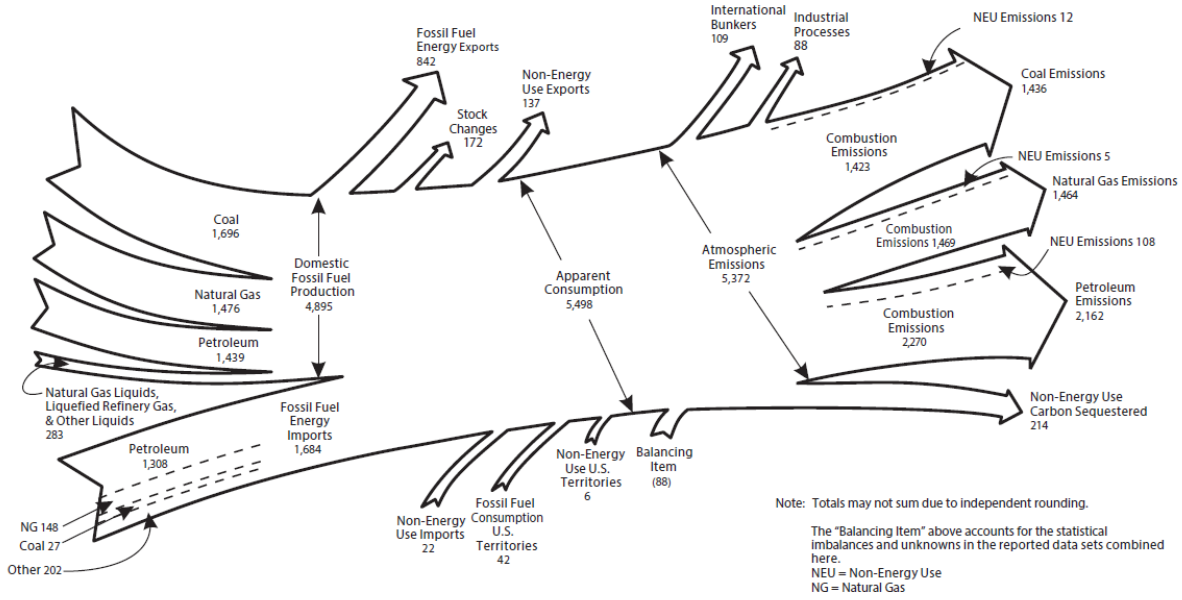


Table 2-4: Emissions from Energy (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**4,907.2**	**5,932.3**	**5,387.2**	**5,180.9**	**5,332.7**	**5,377.8**	**5,231.9**
Fossil Fuel Combustion	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*
Transportation[a]	*1,493.8*	*1,887.0*	*1,707.6*	*1,696.8*	*1,713.0*	*1,742.8*	*1,736.4*
Industrial[a]	*842.5*	*828.0*	*775.0*	*782.9*	*812.2*	*806.1*	*805.5*
Residential	*338.3*	*357.8*	*325.5*	*282.5*	*329.7*	*345.4*	*319.6*
Commercial[a]	*217.4*	*223.5*	*220.4*	*196.7*	*221.0*	*228.7*	*246.2*
U.S. Territories	*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
Natural Gas Systems	37.7	30.1	35.7	35.2	38.5	42.4	42.4
Incineration of Waste	8.0	12.5	10.6	10.4	10.4	10.6	10.7
Petroleum Systems	3.6	3.9	4.2	3.9	3.7	3.6	3.6
Biomass-Wood[b]	*215.2*	*206.9*	*195.2*	*194.9*	*211.6*	*217.7*	*198.7*
International Bunker Fuels[c]	*103.5*	*113.1*	*111.7*	*105.8*	*99.8*	*103.2*	*110.8*
Biofuels-Ethanol[b]	*4.2*	*22.9*	*72.9*	*72.8*	*74.7*	*76.1*	*78.9*
Biofuels-Biodiesel[b]	*0.0*	*0.9*	*8.3*	*8.5*	*13.5*	*13.3*	*14.1*
CH_4	**367.3**	**286.6**	**289.5**	**284.1**	**284.6**	**286.8**	**278.6**
Natural Gas Systems	194.1	159.7	154.5	156.2	159.2	162.5	162.4
Petroleum Systems	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Coal Mining	55.5	46.0	48.0	46.4	44.5	43.0	39.9
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
Mobile Combustion[a]	5.6	2.8	2.3	2.2	2.1	2.1	2.0
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**53.6**	**56.4**	**44.4**	**42.1**	**41.7**	**40.3**	**38.6**
Stationary Combustion	11.9	20.2	21.3	21.4	22.9	23.4	23.1
Mobile Combustion[a]	41.2	35.7	22.8	20.4	18.5	16.6	15.1
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3

International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*
Total	**5,328.1**	**6,275.3**	**5,721.2**	**5,507.0**	**5,659.1**	**5,704.9**	**5,549.1**

+ Does not exceed 0.05 MMT CO_2 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 LULUCF.

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

Note: Totals may not sum due to independent rounding.

Carbon dioxide emissions from fossil fuel combustion are presented in Table 2-5 based on the underlying U.S. energy consumer data collected by the U.S. Energy Information Administration (EIA). Estimates of CO_2 emissions from fossil fuel combustion are calculated from these EIA "end-use sectors" based on total consumption and appropriate fuel properties (any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report). EIA's fuel consumption data for the electric power sector are comprised of electricity-only and combined-heat-and-power (CHP) plants within the North American Industry Classification System (NAICS) 22 category whose primary business is to sell electricity, or electricity and heat, to the public (nonutility power producers can be included in this sector as long as they meet they electric power sector definition). EIA statistics for the industrial sector include fossil fuel consumption that occurs in the fields of manufacturing, agriculture, mining, and construction. EIA's fuel consumption data for the transportation sector consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. EIA's fuel consumption data for the industrial sector consists of all facilities and equipment used for producing, processing, or assembling goods (EIA includes generators that produce electricity and/or useful thermal output primarily to support on-site industrial activities in this sector). EIA's fuel consumption data for the residential sector consist of living quarters for private households. EIA's fuel consumption data for the commercial sector consist of service-providing facilities and equipment from private and public organizations and businesses (EIA includes generators that produce electricity and/or useful thermal output primarily to support the activities at commercial establishments in this sector). Table 2-5 and Figure 2-7 summarize CO_2 emissions from fossil fuel combustion by end-use sector. Figure 2-8 further describes the total emissions from fossil fuel combustion, separated by end-use sector, including CH_4 and N_2O in addition to CO_2.

Table 2-5: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (MMT CO_2 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.

Figure 2-7: 2015 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO_2 Eq.)

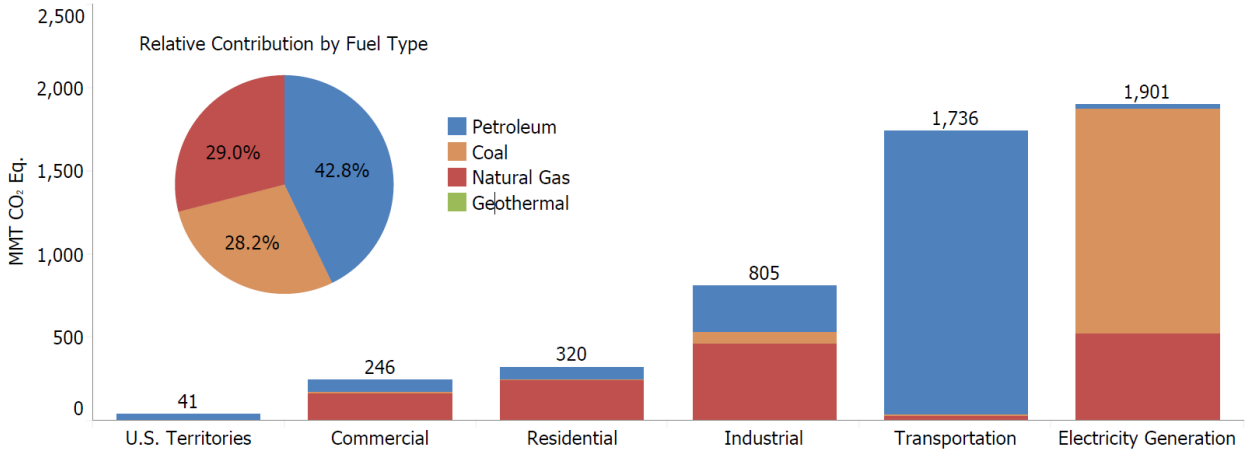
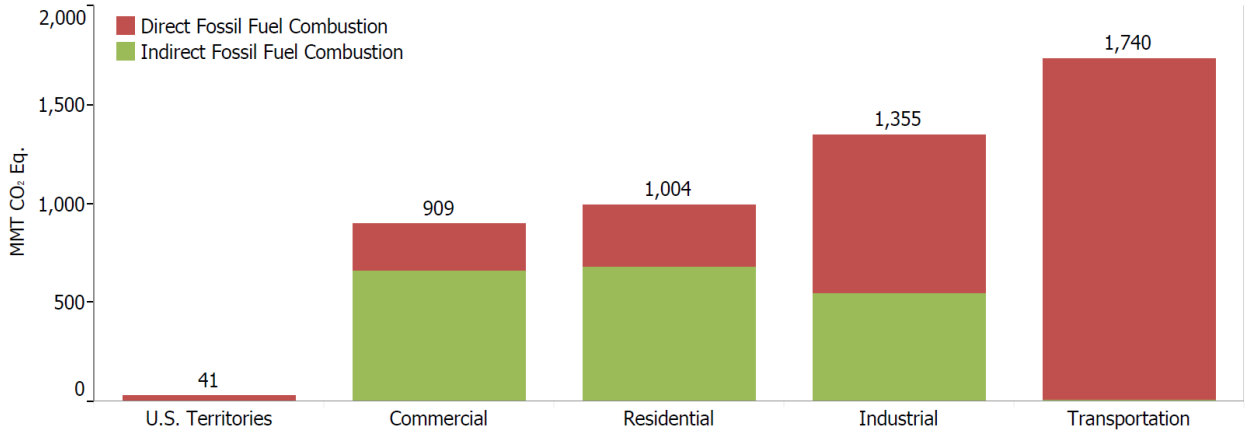
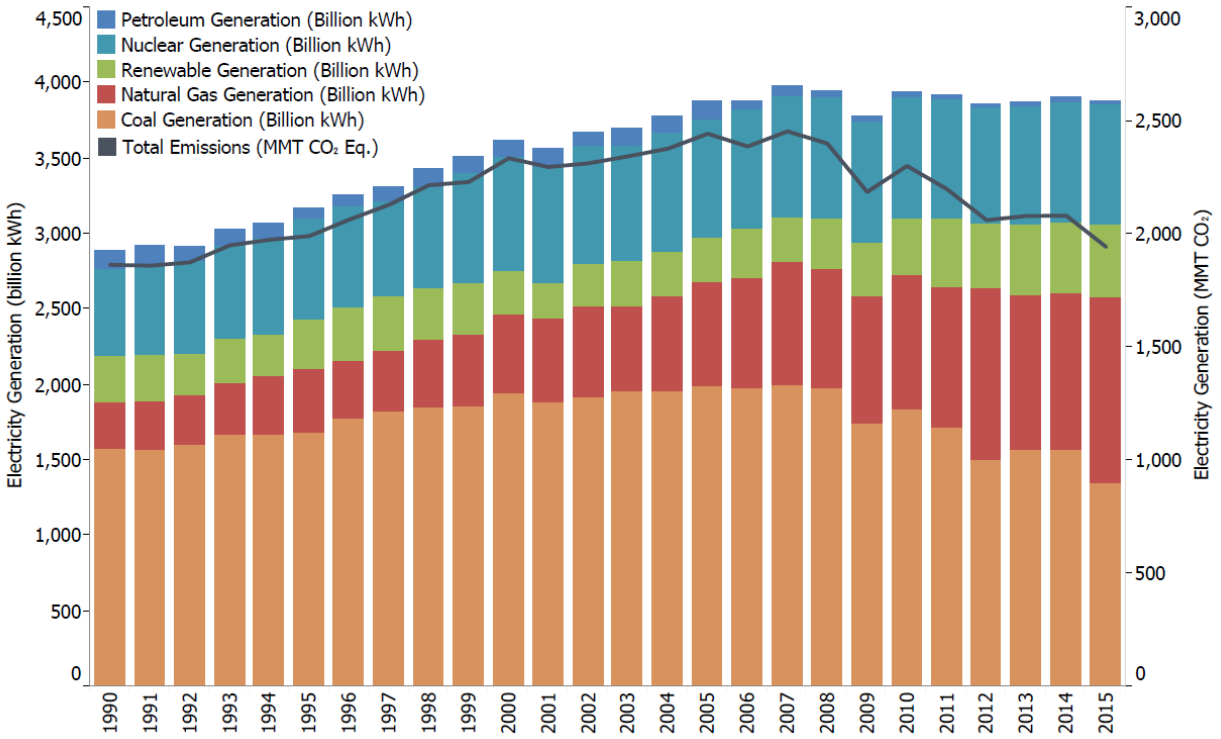


Figure 2-8: 2015 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion (MMT CO_2 Eq.)



The main driver of emissions in the Energy sector is CO_2 from fossil fuel combustion. Electricity generation is the largest emitter of CO_2, and electricity generators consumed 34 percent of U.S. energy from fossil fuels and emitted 38 percent of the CO_2 from fossil fuel combustion in 2015. Changes in electricity demand and the carbon intensity of fuels used for electricity generation have a significant impact on CO_2 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 CO_2 Eq. per QBtu has significantly decreased by 16 percent during that same timeframe. This decoupling of electricity generation and the resulting emissions is shown below in Figure 2-9.

Figure 2-9: Electricity Generation (Billion kWh) and Emissions (MMT CO_2 Eq.)



Electricity generation emissions can also be allocated to the end-use sectors that are consuming that electricity, as presented in Table 2-5. The transportation end-use sector accounted for 1,740.1 MMT CO_2 Eq. in 2015 or approximately 34 percent of total CO_2 emissions from fossil fuel combustion. The industrial end-use sector accounted for 27 percent of CO_2 emissions from fossil fuel combustion. The residential and commercial end-use sectors accounted for 20 and 18 percent, respectively, of CO_2 emissions from fossil fuel combustion. Both of these end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing 68 and 73 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the twenty six-year period from 1990 through 2015 included the following:

- Total CO_2 emissions from fossil fuel combustion increased from 4,740.3 MMT CO_2 Eq. in 1990 to 5,049.8 MMT CO_2 Eq. in 2015 – a 6.5 percent total increase over the twenty six-year period. From 2014 to 2015, these emissions decreased by 152.5 MMT CO_2 Eq. (2.9 percent).
- Methane emissions from natural gas systems and petroleum systems (combined here) decreased from 249.5 MMT CO_2 Eq. in 1990 to 202.3 MMT CO_2 Eq. (47.2 MMT CO_2 Eq. or 18.9 percent) from 1990 to 2015. Natural gas systems CH_4 emissions decreased by 31.6 MMT CO_2 Eq. (16.3 percent) since 1990, largely due to a 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. Petroleum systems CH_4 emissions decreased by 15.6 MMT CO_2 Eq. (or 28.1 percent) since 1990. This decrease is due primarily to decreases in emissions from associated gas venting.
- Carbon dioxide emissions from non-energy uses of fossil fuels increased by 7.9 MMT CO_2 Eq. (6.8 percent) from 1990 through 2015. Emissions from non-energy uses of fossil fuels were 125.5 MMT CO_2 Eq. in 2015, which constituted 2.3 percent of total national CO_2 emissions, approximately the same proportion as in 1990.

- Nitrous oxide emissions from stationary combustion increased by 11.2 MMT CO_2 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.
- Nitrous oxide emissions from mobile combustion decreased by 26.1 MMT CO_2 Eq. (63.3 percent) from 1990 through 2015, primarily as a result of N_2O national emission control standards and emission control technologies for on-road vehicles.
- Carbon dioxide emissions from incineration of waste (10.7 MMT CO_2 Eq. in 2015) increased by 2.7 MMT CO_2 Eq. (34.3 percent) from 1990 through 2015, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

The decrease in CO_2 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.

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 CO_2, CH_4, and N_2O. These processes are shown in Figure 2-10. Industrial processes also release HFCs, PFCs, SF_6, and NF_3 and other fluorinated compounds. In addition to the use of HFCs and some PFCs as substitutes for ozone depleting substances (ODS), fluorinated compounds such as HFCs, PFCs, SF_6, NF_3, and others 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. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-10: 2015 Industrial Processes and Product Use Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

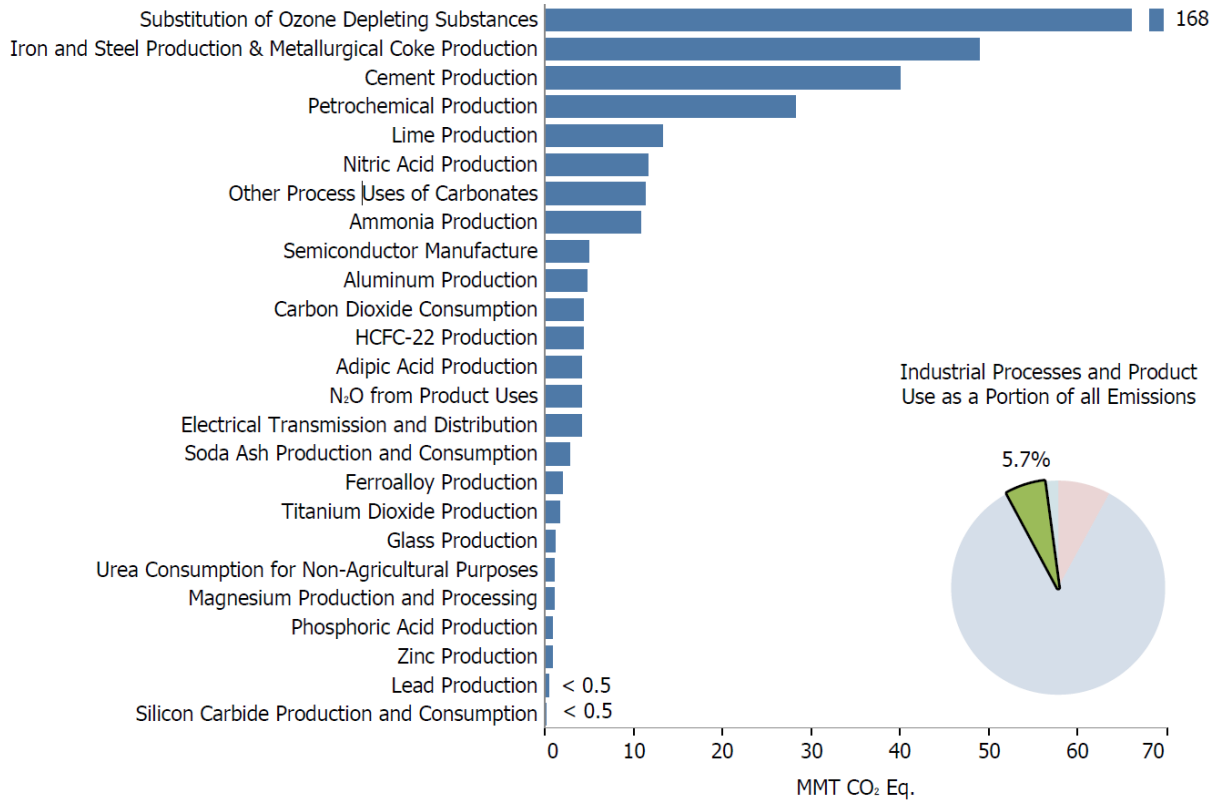


Table 2-6: Emissions from Industrial Processes and Product Use (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**208.8**	**191.7**	**174.3**	**171.0**	**172.9**	**179.3**	**170.7**
Iron and Steel Production & Metallurgical Coke Production	101.5	68.0	61.1	55.4	53.3	58.6	48.9
Iron and Steel Production	*99.0*	*66.0*	*59.7*	*54.9*	*51.5*	*56.6*	*46.0*
Metallurgical Coke Production	*2.5*	*2.0*	*1.4*	*0.5*	*1.8*	*2.0*	*2.8*
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
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
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	+	+	+	+	+	+	+
CH_4	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**

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	+	+	+	+	+	+	+
Iron and Steel Production	+	+	+	+	+	+	+
Metallurgical Coke Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	**31.6**	**22.8**	**25.6**	**20.4**	**19.0**	**20.8**	**20.3**
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Semiconductor Manufacture	+	0.1	0.2	0.2	0.2	0.2	0.2
HFCs	**46.6**	**120.0**	**154.3**	**155.9**	**159.0**	**166.7**	**173.2**
Substitution of Ozone Depleting Substances[a]	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	+	+	+	+	+	+
SF_6	**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
NF_3	**+**	**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	**340.4**	**353.4**	**371.0**	**360.9**	**363.7**	**379.8**	**375.9**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Overall, emissions from the IPPU sector increased by 10.4 percent from 1990 to 2015. Significant trends in emissions from IPPU source categories over the twenty-six-year period from 1990 through 2015 included the following:

- Hydrofluorocarbon and perfluorocarbon emissions from ODS substitutes have been increasing from small amounts in 1990 to 168.5 MMT CO_2 Eq. in 2015. This increase was in large part the result of efforts to phase out chlorofluorocarbons (CFCs) and other ODSs 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.
- Combined CO_2 and CH_4 emissions from iron and steel production and metallurgical coke production decreased by 16.6 percent to 48.9 MMT CO_2 Eq. from 2014 to 2015, and have declined overall by 52.6 MMT CO_2 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 CO_2 Eq. in 2015) decreased by 2.2 MMT CO_2 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.
- Urea consumption for non-agricultural purposes (1.1 MMT CO_2 Eq. in 2015) decreased by 2.7 MMT CO_2 Eq. (70.2 percent) since 1990. From 1990 to 2007, emissions increased by 31 percent to a peak of 4.9 MMT CO_2 Eq., before decreasing by 77 percent to 2015 levels.
- Nitrous oxide emissions from adipic acid production were 4.3 MMT CO_2 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.

- PFC emissions from aluminum production decreased by 90.7 percent (19.5 MMT CO_2 Eq.) from 1990 to 2015, due to both industry emission reduction efforts and lower domestic aluminum production.

Agriculture

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 CO_2 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 CH_4 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. N_2O 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 CO_2 emissions from anthropogenic activities. Figure 2-11 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

Figure 2-11: 2015 Agriculture Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

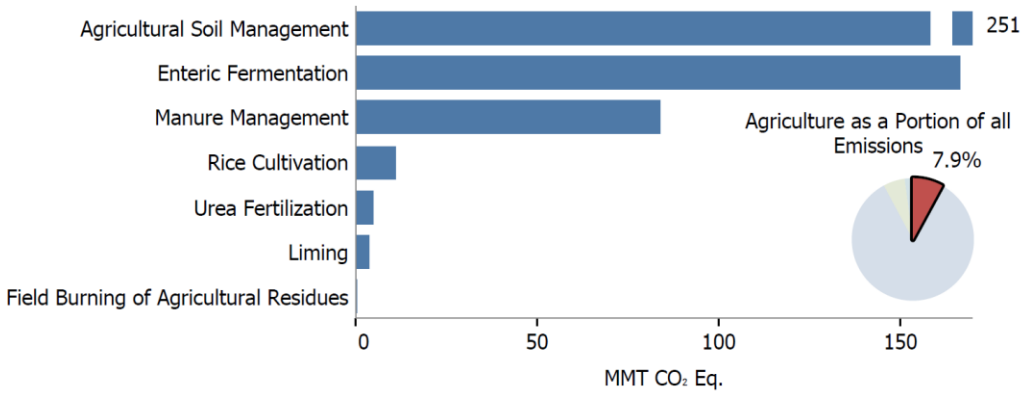


Table 2-7: Emissions from Agriculture (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**7.1**	**7.9**	**8.0**	**10.2**	**8.4**	**8.4**	**8.8**
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
CH_4	**217.6**	**242.1**	**246.3**	**244.0**	**240.4**	**238.7**	**244.3**
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Manure Management	37.2	56.3	63.0	65.6	63.3	62.9	66.3
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
N_2O	**270.6**	**276.4**	**287.6**	**271.7**	**268.1**	**267.6**	**269.1**
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Manure Management	14.0	16.5	17.4	17.5	17.5	17.5	17.7
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**495.3**	**526.4**	**541.9**	**525.9**	**516.9**	**514.7**	**522.3**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Agriculture source categories include the following:

- Agricultural soils produced approximately 75.1 percent of N_2O emissions in the United States in 2015. Estimated emissions from this source in 2015 were 251.3 MMT CO_2 Eq. Annual N_2O 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.
- Enteric fermentation is the largest anthropogenic source of CH_4 emissions in the United States. In 2015, enteric fermentation CH_4 emissions were 166.5 MMT CO_2 Eq. (25.4 percent of total CH_4 emissions), which represents an increase of 2.4 MMT CO_2 Eq. (1.5 percent) since 1990. This increase in emissions from 1990 to 2015 in enteric fermentation 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.
- Liming and urea fertilization are the only source of CO_2 emissions reported in the Agriculture sector. Estimated emissions from these sources were 3.8 and 5.0 MMT CO_2 Eq., respectively. Liming and urea fertilization emissions increased by 5.6 percent and 5.3 percent, respectively, relative to 2014, and decreased by 18.4 percent and increased by 108.2 percent, respectively since 1990.
- Overall, emissions from manure management increased 64.2 percent between 1990 and 2015. This encompassed an increase of 78.3 percent for CH_4, from 37.2 MMT CO_2 Eq. in 1990 to 66.3 MMT CO_2 Eq. in 2015; and an increase of 26.6 percent for N_2O, from 14.0 MMT CO_2 Eq. in 1990 to 17.7 MMT CO_2 Eq. in 2015. The majority of the increase observed in CH_4 resulted from swine and dairy cattle manure, where emissions increased 58 and 136 percent, respectively, from 1990 to 2015. From 2014 to 2015, there was a 5.4 percent increase in total CH_4 emissions from manure management, mainly due to minor shifts in the animal populations and the resultant effects on manure management system allocations.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also influence the carbon (C) stock fluxes on these lands and cause emissions of CH_4 and N_2O. Overall, managed land is a net sink for CO_2 (C sequestration) in the United States. The drivers of fluxes on managed lands include, for example, forest management practices, tree planting in urban areas, the management of agricultural

soils, the landfilling of yard trimmings and food scraps, and activities that cause changes in C stocks in coastal wetlands. The main drivers for net forest sequestration include net forest growth, increasing forest area, and a net accumulation of C stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements,* is driven primarily by C stock gains in urban forests through net tree growth and increased urban area, as well as long-term accumulation of C in landfills from additions of yard trimmings and food scraps.

The LULUCF sector in 2015 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 778.7 MMT CO_2 Eq. (Table 2-3).[1] This represents an offset of approximately 11.8 percent of total (i.e., gross) greenhouse gas emissions in 2015. Emissions of CH_4 and N_2O from LULUCF activities in 2015 were 19.7 MMT CO_2 Eq. and represent 0.3 percent of total greenhouse gas emissions.[2] 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 CO_2 emissions from *Land Converted to Settlements.*

Carbon dioxide removals from C stock changes are presented in Table 2-8 along with CH_4 and N_2O emissions for LULUCF source categories. Forest fires were the largest source of CH_4 emissions from LULUCF in 2015, totaling 7.3 MMT CO_2 Eq. (292 kt of CH_4). *Coastal Wetlands Remaining Coastal Wetlands* resulted in CH_4 emissions of 3.6 MMT CO_2 Eq. (143 kt of CH_4). Grassland fires resulted in CH_4 emissions of 0.4 MMT CO_2 Eq. (16 kt of CH_4). *Peatlands Remaining Peatlands*, *Land Converted to Wetlands*, and *Drained Organic Soils* resulted in CH_4 emissions of less than 0.05 MMT CO_2 Eq. each.

Forest fires were also the largest source of N_2O emissions from LULUCF in 2015, totaling 4.8 MMT CO_2 Eq. (16 kt of N_2O). Nitrous oxide emissions from fertilizer application to settlement soils in 2015 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). This represents an increase of 76.6 percent since 1990. Additionally, the application of synthetic fertilizers to forest soils in 2015 resulted in N_2O emissions of 0.5 MMT CO_2 Eq. (2 kt of N_2O). 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 N_2O emissions of 0.4 MMT CO_2 Eq. (1 kt of N_2O). *Coastal Wetlands Remaining Coastal Wetlands* and *Drained Organic Soils* resulted in N_2O emissions of 0.1 MMT CO_2 Eq. each (less than 0.5 kt of N_2O), and *Peatlands Remaining Peatlands* resulted in N_2O emissions of less than 0.05 MMT CO_2 Eq. (see Table 2-8).

Table 2-8: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 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
CH_4	**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

[1] 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.*

[2] LULUCF emissions include the CH_4 and N_2O emissions reported for *Peatlands Remaining Peatlands*, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands*; and N_2O emissions from Forest Soils and Settlement Soils.

Grassland Remaining Grassland: Grassland 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	+	+	+	+	+	+	+
N_2O	**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: Grassland 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 CO_2 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 CH_4 and N_2O emissions reported for *Peatlands Remaining Peatlands*, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands*; and N_2O emissions from Forest Soils and Settlement Soils.

[e] The LULUCF Sector Net Total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

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

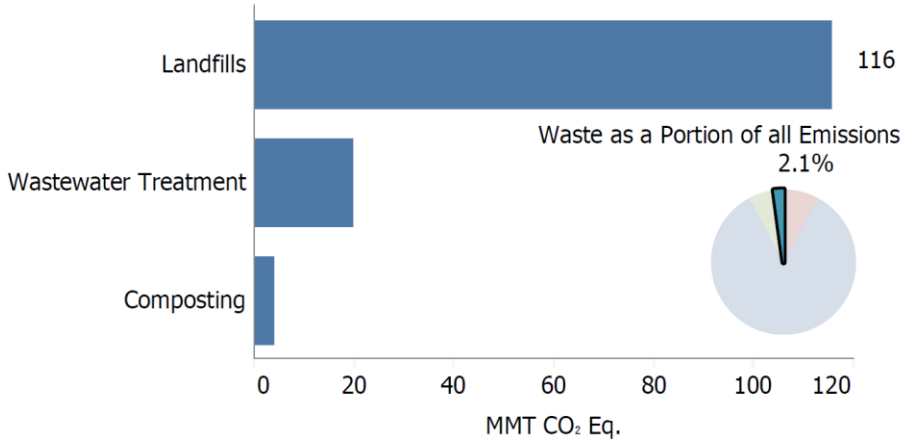
Other significant trends from 1990 to 2015 in emissions from LULUCF categories include:

- Annual C sequestration by forest land (i.e., annual C stock accumulation in the five C pools and harvested wood products for *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*) has decreased by approximately 6.1 percent since 1990. This is primarily due to decreased C stock gains in *Land Converted to Forest Land* and the harvested wood products pools within *Forest Land Remaining Forest Land*.
- Annual C sequestration from *Settlements Remaining Settlements* (which includes organic soils, urban trees, and landfilled yard trimmings and food scraps) has increased by 18.4 percent over the period from 1990 to 2015. This is primarily due to an increase in urbanized land area in the United States.
- Annual emissions from *Land Converted to Grassland* increased by approximately 14.4 percent from 1990 to 2015 due to losses in aboveground biomass, belowground biomass, dead wood, and litter C stocks from *Forest Land Converted to Grassland*.
- Annual emissions from *Land Converted to Settlements* increased by approximately 83.5 percent from 1990 to 2015 due to losses in aboveground biomass C stocks from *Forest Land Converted to Settlements* and mineral soils C stocks from *Grassland Converted to Settlements*.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-12). In 2015, landfills were the third-largest source of U.S. anthropogenic CH_4 emissions, accounting for 17.6 percent of total U.S. CH_4 emissions.[3] Additionally, wastewater treatment accounts for 14.2 percent of Waste emissions, 2.3 percent of U.S. CH_4 emissions, and 1.5 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2015, and resulted in emissions of 4.0 MMT CO_2 Eq. in 2015. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-9.

Figure 2-12: 2015 Waste Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)



Overall, in 2015, waste activities generated emissions of 139.4 MMT CO_2 Eq., or 2.1 percent of total U.S. greenhouse gas emissions.

Table 2-9: Emissions from Waste (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CH_4	**195.6**	**152.1**	**136.2**	**137.9**	**133.7**	**133.5**	**132.6**
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8
Composting	0.4	1.9	1.9	1.9	2.0	2.1	2.1
N_2O	**3.7**	**6.1**	**6.4**	**6.6**	**6.7**	**6.8**	**6.9**
Wastewater Treatment	3.4	4.4	4.8	4.8	4.9	4.9	5.0
Composting	0.3	1.7	1.7	1.7	1.8	1.9	1.9
Total	**199.3**	**158.2**	**142.6**	**144.4**	**140.4**	**140.2**	**139.4**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from waste source categories include the following:

- From 1990 to 2015, net CH_4 emissions from landfills decreased by 63.8 MMT CO_2 Eq. (35.6 percent), with small increases occurring in interim years. This downward trend in emissions coincided with increased

[3] 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.

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.

- Combined CH_4 and N_2O emissions from composting have generally increased since 1990, from 0.7 MMT CO_2 Eq. to 4.0 MMT CO_2 Eq. in 2015, which represents slightly more than a five-fold increase over the time series. The growth in composting since the 1990s is attributable to primarily two factors: (1) steady growth in population and residential housing, and (2) the enactment of legislation by state and local governments that discouraged the disposal of yard trimmings in landfills.
- From 1990 to 2015, CH_4 and N_2O emissions from wastewater treatment decreased by 0.9 MMT CO_2 Eq. (5.8 percent) and increased by 1.6 MMT CO_2 Eq. (47.0 percent), respectively. Methane emissions from domestic wastewater treatment have decreased since 1999 due to decreasing percentages of wastewater being treated in anaerobic systems, including reduced use of on-site septic systems and central anaerobic treatment systems. Nitrous oxide emissions from wastewater treatment processes gradually increased across the time series as a result of increasing U.S. population and protein consumption.

2.2 Emissions by Economic Sector

Throughout this report, emission estimates are grouped into five sectors (i.e., chapters) defined by the IPCC and detailed above: 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, and agriculture, as well as U.S. Territories.

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). Emissions from industry accounted for about 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 efficiency improvements. The remaining 22 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. Territories. The residential sector accounted for 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 9 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for roughly 7 percent of emissions, while U.S. Territories accounted for less than 1 percent. Carbon dioxide was also emitted and sequestered (in the form of C) 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.

Table 2-10 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-13 shows the trend in emissions by sector from 1990 to 2015.

Figure 2-13: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

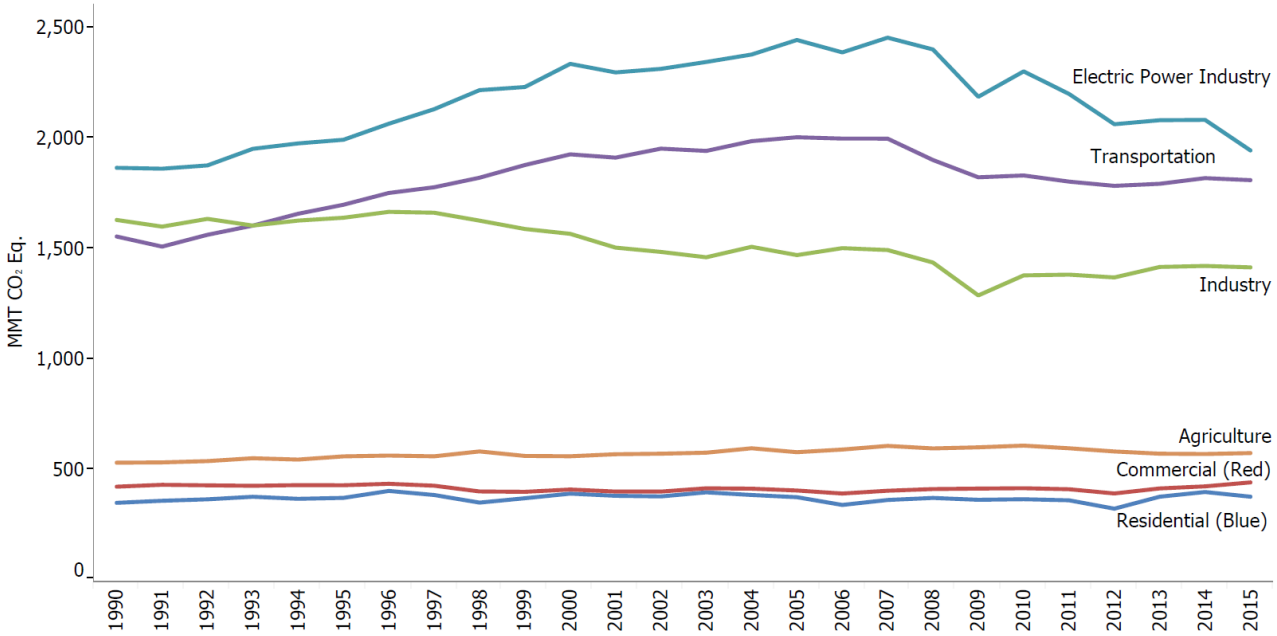


Table 2-10: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq. and Percent of Total in 2015)

Sector/Source	1990	2005	2011	2012	2013	2014	2015[a]	Percent[a,b]
Electric Power Industry	**1,862.5**	**2,441.6**	**2,197.3**	**2,059.9**	**2,078.2**	**2,079.7**	**1,941.4**	**29.5%**
CO_2 from Fossil Fuel Combustion	1,820.8	2,400.9	2,157.7	2,022.2	2,038.1	2,038.0	1,900.7	28.9%
Stationary Combustion	7.7	16.5	18.0	18.2	19.5	20.0	19.9	0.3%
Incineration of Waste	8.4	12.9	10.9	10.7	10.7	10.9	11.0	0.2%
Other Process Uses of Carbonates	2.5	3.2	4.7	4.0	5.2	5.9	5.6	0.1%
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2	0.1%
Transportation	**1,551.2**	**2,001.0**	**1,800.0**	**1,780.7**	**1,790.2**	**1,815.8**	**1,806.6**	**27.4%**
CO_2 from Fossil Fuel Combustion[a]	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4	26.4%
Substitution of Ozone Depleting Substances	+	67.1	60.2	55.1	49.8	47.2	45.1	0.7%
Mobile Combustion[a]	45.7	36.8	23.2	20.6	18.6	16.6	15.2	0.2%
Non-Energy Use of Fuels	11.8	10.2	9.0	8.3	8.8	9.1	10.0	0.2%
Industry	**1,626.3**	**1,467.1**	**1,378.6**	**1,365.9**	**1,413.4**	**1,418.0**	**1,411.6**	**21.4%**
CO_2 from Fossil Fuel Combustion[a]	811.4	780.6	725.4	731.9	762.2	755.3	758.0	11.5%
Natural Gas Systems	231.8	189.8	190.2	191.4	197.7	204.9	204.8	3.1%
Non-Energy Use of Fuels	100.1	120.6	95.8	93.7	109.4	104.7	110.5	1.7%
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9	0.9%
Iron and Steel Production	101.5	68.1	61.1	55.5	53.4	58.6	48.9	0.7%
Petroleum Systems	59.0	49.9	52.2	50.3	48.2	46.6	43.4	0.7%
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9	0.6%
Petrochemical Production	21.5	27.0	26.4	26.6	26.5	26.6	28.2	0.4%
Substitution of Ozone Depleting Substances	+	7.4	17.1	18.8	20.4	22.3	24.7	0.4%
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3	0.2%
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6	0.2%

Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8	0.2%
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4	0.1%
Other Process Uses of Carbonates	2.5	3.2	4.7	4.0	5.2	5.9	5.6	0.1%
HCFC-22 Production	3.6	4.7	4.9	4.5	4.1	5.0	5.0	0.1%
Semiconductor Manufacture	28.3	7.6	6.8	6.4	6.2	5.4	4.8	0.1%
Aluminum Production	1.5	1.4	4.1	4.0	4.2	4.5	4.3	0.1%
Carbon Dioxide Consumption	46.1	20.0	8.8	5.5	4.1	5.0	4.3	0.1%
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3	0.1%
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.1%
Stationary Combustion	4.9	4.6	3.9	3.9	3.9	3.8	3.8	0.1%
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	+
Mobile Combustion[a]	0.9	1.3	1.4	1.4	1.5	1.5	1.4	+
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	**526.7**	**574.3**	**592.0**	**577.6**	**567.5**	**566.1**	**570.3**	**8.7%**
N_2O from Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3	3.8%
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5	2.5%
Manure Management	51.1	72.9	80.4	83.2	80.8	80.4	84.0	1.3%
CO_2 from Fossil Fuel Combustion[a]	31.0	47.4	49.6	51.1	50.0	50.8	47.5	0.7%
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2	0.2%
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0	0.1%
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8	0.1%
Mobile Combustion[a]	0.3	0.5	0.5	0.6	0.6	0.6	0.5	+
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4	+
Stationary Combustion	+	+	+	+	0.1	0.1	0.1	+
Commercial	**418.1**	**400.7**	**406.5**	**387.3**	**410.1**	**419.5**	**437.4**	**6.6%**
CO_2 from Fossil Fuel Combustion[a]	217.4	223.5	220.4	196.7	221.0	228.7	246.2	3.7%
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7	1.8%
Substitution of Ozone Depleting Substances	+	17.6	42.1	44.9	47.4	49.2	50.2	0.8%
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8	0.2%
Human Sewage	3.4	4.4	4.8	4.8	4.9	4.9	5.0	0.1%
Composting	0.7	3.5	3.5	3.7	3.9	4.0	4.0	0.1%
Stationary Combustion	1.4	1.4	1.4	1.2	1.3	1.4	1.5	+
Residential	**344.9**	**370.4**	**356.3**	**318.4**	**372.6**	**393.9**	**372.7**	**5.7%**
CO_2 from Fossil Fuel Combustion	338.3	357.8	325.5	282.5	329.7	345.4	319.6	4.9%
Substitution of Ozone Depleting Substances	0.3	7.7	25.9	31.4	37.0	42.6	48.4	0.7%
Stationary Combustion	6.3	4.9	4.9	4.5	5.9	6.0	4.7	0.1%
U.S. Territories	**33.3**	**58.1**	**46.0**	**48.5**	**48.1**	**46.6**	**46.6**	**0.7%**
CO_2 from Fossil Fuel Combustion	27.6	49.7	40.9	43.5	42.5	41.4	41.4	0.6%
Non-Energy Use of Fuels	5.7	8.1	5.0	4.8	5.4	5.1	5.1	0.1%
Stationary Combustion	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**	**100.0%**

LULUCF Sector Net Total[c]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**	**(11.5%)**
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**	**88.5%**

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

+ Does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

[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] Percent of total (gross) emissions excluding emissions from LULUCF for 2015.

[c] The LULUCF Sector Net Total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

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

Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view 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). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 29 percent of total U.S. greenhouse gas emissions in 2015. Emissions increased by 4 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions decreased from 2014 to 2015 by 6.7 percent, primarily due to decreased CO_2 emissions from fossil fuel combustion due to an increase in natural gas consumption, and decreased coal consumption. Electricity sales to the residential and commercial end-use sectors in 2015 decreased by 0.2 percent and increased by 0.6 percent, respectively. The trend in the residential and commercial sectors can largely be attributed to warmer, less energy-intensive winter conditions compared to 2014. Electricity sales to the industrial sector in 2015 decreased by approximately 1.1 percent. Overall, in 2015, the amount of electricity generated (in kWh) decreased by 0.2 percent from the previous year. This decrease in generation contributed to a reduction in CO_2 emissions from the electric power sector of 6.7 percent, as the consumption of CO_2-intensive coal for electricity generation decreased by 13.9 percent and natural gas generation increased by 18.7 percent. The consumption of petroleum for electricity generation decreased by 6.6 percent in 2015 relative to 2014. Table 2-11 provides a detailed summary of emissions from electricity generation-related activities.

Table 2-11: Electricity Generation-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Fuel Type or Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**1,831.2**	**2,416.5**	**2,172.9**	**2,036.6**	**2,053.7**	**2,054.5**	**1,917.0**
Fossil Fuel Combustion	1,820.8	2,400.9	2,157.7	2,022.2	2,038.1	2,038.0	1,900.7
Coal	*1,547.6*	*1,983.8*	*1,722.7*	*1,511.2*	*1,571.3*	*1,569.1*	*1,350.5*
Natural Gas	*175.3*	*318.8*	*408.8*	*492.2*	*444.0*	*443.2*	*526.1*
Petroleum	*97.5*	*97.9*	*25.8*	*18.3*	*22.4*	*25.3*	*23.7*
Geothermal	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0	12.5	10.6	10.4	10.4	10.6	10.7
Other Process Uses of Carbonates	2.5	3.2	4.7	4.0	5.2	5.9	5.6
CH_4	**0.3**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Stationary Sources (Electricity Generation)	0.3	0.5	0.4	0.4	0.4	0.4	0.4
Incineration of Waste	+	+	+	+	+	+	+
N_2O	**7.8**	**16.4**	**17.9**	**18.1**	**19.4**	**19.9**	**19.8**
Stationary Sources (Electricity Generation)	7.4	16.0	17.6	17.8	19.1	19.6	19.5
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
SF_6	**23.1**	**8.3**	**6.0**	**4.8**	**4.6**	**4.8**	**4.2**
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2

Total	**1,862.5**	**2,441.6**	**2,197.3**	**2,059.9**	**2,078.2**	**2,079.7**	**1,941.4**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Includes only stationary combustion emissions related to the generation of electricity.

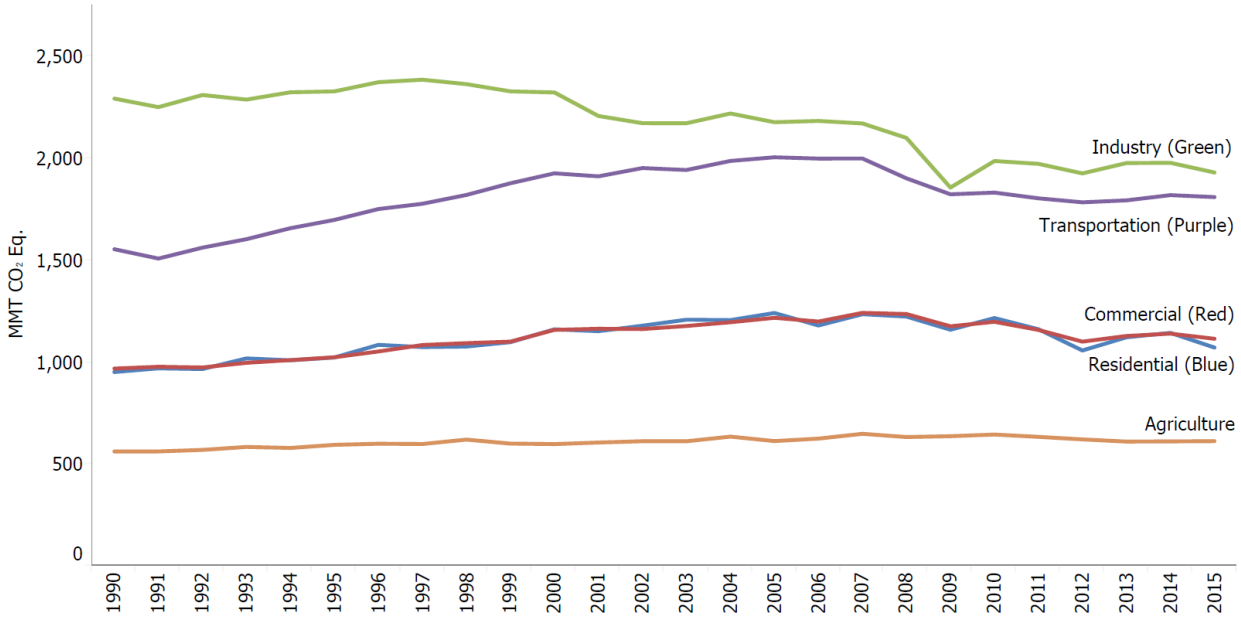
Note: Totals may not sum due to independent rounding.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to each economic sector's share of retail sales of electricity consumption (EIA 2017 and Duffield 2006). These source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Incineration of Waste, Other Process Uses of Carbonates, and SF_6 from Electrical Transmission and Distribution Systems. Note that only 50 percent of the Other Process Uses of Carbonates emissions were associated with electricity generation and distributed as described; the remainder of Other Process Uses of Carbonates emissions were attributed to the industrial processes economic end-use sector.[4]

When emissions from electricity are distributed among these sectors, industrial activities account for the largest share of total U.S. greenhouse gas emissions (29.3 percent), followed closely by emissions from transportation (27.5 percent). Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included. In all sectors except agriculture, CO_2 accounts for more than 82 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-12 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-14 shows the trend in these emissions by sector from 1990 to 2015.

Figure 2-14: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO_2 Eq.)



[4] 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.

Table 2-12: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (MMT CO_2 Eq.) and Percent of Total in 2015

Sector/Gas	1990	2005	2011	2012	2013	2014	2015[a]	Percent[a,b]
Industry	**2,293.9**	**2,178.1**	**1,973.6**	**1,926.7**	**1,977.4**	**1,978.7**	**1,931.1**	**29.3%**
Direct Emissions[a]	**1,626.3**	**1,467.1**	**1,378.6**	**1,365.9**	**1,413.4**	**1,418.0**	**1,411.6**	**21.4%**
CO_2	1,159.2	1,123.7	1,030.6	1,031.6	1,081.5	1,079.3	1,079.5	16.4%
CH_4	355.4	278.4	281.9	277.1	276.3	278.5	271.5	4.1%
N_2O	35.4	26.7	29.2	24.0	22.7	24.4	23.8	0.4%
HFCs, PFCs, SF_6, and NF_3	76.3	38.2	36.8	33.1	32.9	35.7	36.8	0.6%
Electricity-Related	**667.6**	**711.0**	**595.0**	**560.8**	**564.0**	**560.7**	**519.6**	**7.9%**
CO_2	656.4	703.7	588.4	554.4	557.4	553.9	513.1	7.8%
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+
N_2O	2.8	4.8	4.9	4.9	5.3	5.4	5.3	0.1%
SF_6	8.3	2.4	1.6	1.3	1.2	1.3	1.1	+
Transportation	**1,554.4**	**2,005.9**	**1,804.3**	**1,784.7**	**1,794.3**	**1,820.0**	**1,810.4**	**27.5%**
Direct Emissions[a]	**1,551.2**	**2,001.0**	**1,800.0**	**1,780.7**	**1,790.2**	**1,815.8**	**1,806.6**	**27.4%**
CO_2	1,505.6	1,897.2	1,716.6	1,705.0	1,721.8	1,752.0	1,746.3	26.5%
CH_4	5.4	2.4	1.9	1.8	1.7	1.7	1.6	+
N_2O	40.3	34.3	21.3	18.8	16.9	15.0	13.6	0.2%
HFCs[c]	+	67.1	60.2	55.1	49.8	47.2	45.1	0.7%
Electricity-Related	**3.1**	**4.8**	**4.3**	**3.9**	**4.1**	**4.1**	**3.8**	**0.1%**
CO_2	3.1	4.8	4.3	3.9	4.0	4.1	3.8	0.1%
CH_4	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+
Commercial	**968.4**	**1,217.6**	**1,158.1**	**1,100.6**	**1,128.5**	**1,139.9**	**1,114.8**	**16.9%**
Direct Emissions[a]	**418.1**	**400.7**	**406.5**	**387.3**	**410.1**	**419.5**	**437.4**	**6.6%**
CO_2	217.4	223.5	220.4	196.7	221.0	228.7	246.2	3.7%
CH_4	196.7	153.2	137.3	138.8	134.7	134.5	133.7	2.0%
N_2O	4.1	6.4	6.7	6.8	7.0	7.1	7.2	0.1%
HFCs	+	17.6	42.1	44.9	47.4	49.2	50.2	0.8%
Electricity-Related	**550.3**	**816.9**	**751.6**	**713.3**	**718.3**	**720.4**	**677.3**	**10.3%**
CO_2	541.1	808.5	743.3	705.3	709.9	711.7	668.8	10.2%
CH_4	0.1	0.2	0.2	0.1	0.2	0.2	0.2	+
N_2O	2.3	5.5	6.1	6.3	6.7	6.9	6.9	0.1%
SF_6	6.8	2.8	2.0	1.7	1.6	1.7	1.4	+%
Residential	**951.5**	**1,241.3**	**1,161.5**	**1,057.2**	**1,122.0**	**1,143.7**	**1,071.6**	**16.3%**
Direct Emissions	**344.9**	**370.4**	**356.3**	**318.4**	**372.6**	**393.9**	**372.7**	**5.7%**
CO_2	338.3	357.8	325.5	282.5	329.7	345.4	319.6	4.9%
CH_4	5.2	4.1	4.0	3.7	5.0	5.0	3.9	0.1%
N_2O	1.0	0.9	0.8	0.7	1.0	1.0	0.8	+
HFCs	0.3	7.7	25.9	31.4	37.0	42.6	48.4	0.7%
Electricity-Related	**606.6**	**870.8**	**805.2**	**738.8**	**749.3**	**749.8**	**698.9**	**10.6%**
CO_2	596.4	861.9	796.3	730.4	740.5	740.7	690.1	10.5%
CH_4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.5	5.8	6.6	6.5	7.0	7.2	7.1	0.1%
SF_6	7.5	2.9	2.2	1.7	1.7	1.7	1.5	+
Agriculture	**561.5**	**612.4**	**633.1**	**620.6**	**609.9**	**610.8**	**612.0**	**9.3%**
Direct Emissions[a]	**526.7**	**574.3**	**592.0**	**577.6**	**567.5**	**566.1**	**570.3**	**8.7%**
CO_2	38.1	55.2	57.6	61.3	58.4	59.2	56.3	0.9%
CH_4	217.7	242.3	246.5	244.2	240.6	238.9	244.5	3.7%
N_2O	270.9	276.8	288.0	272.1	268.5	268.0	269.5	4.1%
Electricity-Related	**34.8**	**38.1**	**41.1**	**43.1**	**42.4**	**44.7**	**41.7**	**0.6%**
CO_2	34.2	37.7	40.6	42.6	41.9	44.1	41.2	0.6%
CH_4	+	+	+	+	+	+	+	+
N_2O	0.1	0.3	0.3	0.4	0.4	0.4	0.4	+
SF_6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	+
U.S. Territories	**33.3**	**58.1**	**46.0**	**48.5**	**48.1**	**46.6**	**46.6**	**0.7%**

Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**	**100.0%**
LULUCF Sector Net Total[d]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**	**(11.5%)**
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**	**88.5%**

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

+ Does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

[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] Percent of total gross emissions excluding emissions from LULUCF for year 2015.

[c] Includes primarily HFC-134a.

[d] The LULUCF Sector Net Total is the net sum of all CH_4 and N_2O 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.

Industry

The industry end-use sector includes CO_2 emissions from fossil fuel combustion from all manufacturing facilities, in aggregate. This end-use sector also includes emissions that are produced as a byproduct of the non-energy-related industrial process activities. The variety of activities producing these non-energy-related emissions includes CH_4 emissions from petroleum and natural gas systems, fugitive CH_4 emissions from coal mining, by-product CO_2 emissions from cement manufacture, and HFC, PFC, SF_6, and NF_3 byproduct emissions from semiconductor manufacture, to name a few. Since 1990, industrial sector emissions have declined. The decline has occurred both in direct emissions and indirect emissions associated with electricity use. In theory, emissions from the industrial end-use sector should be highly correlated with economic growth and industrial output, but heating of industrial buildings and agricultural energy consumption are also affected by weather conditions. In addition, structural changes within the U.S. economy that lead to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) also have a significant effect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 27.5 percent of U.S. greenhouse gas emissions in 2015. The largest sources of transportation greenhouse gases in 2015 were passenger cars (41.9 percent), freight trucks (22.9 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18.0 percent), commercial aircraft (6.6 percent), rail (2.6 percent), other aircraft (2.2 percent), pipelines (2.1 percent), and ships and boats (1.8 percent). These figures include direct CO_2, CH_4, and N_2O emissions from fossil fuel combustion used in transportation and emissions from non-energy use (i.e., lubricants) used in transportation, as well as HFC emissions from mobile air conditioners and refrigerated transport allocated to these vehicle types.

In terms of the overall trend, from 1990 to 2015, total transportation emissions increased due, in large part, to increased demand for travel. The number of vehicle miles traveled (VMT) by light-duty motor vehicles (passenger cars and light-duty trucks) increased 40 percent from 1990 to 2015,[5] as a result of a confluence of factors including population growth, economic growth, urban sprawl, and periods of low fuel prices. The decline in new light-duty vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light-duty trucks, which grew

[5] 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.

from about 30 percent of new vehicle sales in 1990 to 48 percent in 2004. Starting in 2005, average new vehicle fuel economy began to increase while light-duty VMT grew only modestly for much of the period. Light-duty VMT grew by less than one percent or declined each year between 2005 and 2013[6] and has since grown a faster rate (1.2 percent from 2013 to 2014, and 2.6 percent from 2014 to 2015). Average new vehicle fuel economy has improved almost every year since 2005 and the truck share decreased to about 33 percent in 2009, and has since varied from year to year between 36 percent and 43 percent. Truck share is about 43 percent of new vehicles in model year 2015 (EPA 2016a). Table 2-13 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals. It is important to note that there was a change in methods between 2014 and 2015 used to estimate gasoline consumption in the transportation sector. In the absence of this change, CO_2 emissions from passenger cars, light-duty trucks, and other on-road vehicles using gasoline would likely have been higher in 2015.[7]

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to 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. The primary driver of transportation-related emissions was CO_2 from fossil fuel combustion, which increased by 16 percent from 1990 to 2015.[8] This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 45.1 MMT CO_2 Eq. in 2015, led to an increase in overall emissions from transportation activities of 16 percent.[9]

Table 2-13: Transportation-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Vehicle	1990	2005	2011	2012	2013	2014	2015[a]
Passenger Cars	**656.7**	**708.7**	**774.1**	**767.7**	**763.0**	**778.4**	**758.4**
CO_2	629.3	660.1	736.9	735.5	735.5	753.7	735.7
CH_4	3.2	1.2	1.2	1.1	1.1	1.0	1.0
N_2O	24.1	15.7	12.1	10.5	9.2	7.8	6.9
HFCs	0.0	31.7	23.9	20.6	17.3	16.0	14.9
Light-Duty Trucks	**335.2**	**552.2**	**331.5**	**325.1**	**322.2**	**343.7**	**325.1**
CO_2	320.7	503.3	293.8	290.5	290.8	314.4	298.0
CH_4	1.7	0.9	0.4	0.4	0.3	0.3	0.3
N_2O	12.8	14.7	5.6	4.9	4.3	4.0	3.4
HFCs	0.0	33.3	31.7	29.3	26.7	25.0	23.4
Medium- and Heavy-Duty Trucks	**231.4**	**398.9**	**388.4**	**388.8**	**395.8**	**408.3**	**415.0**
CO_2	230.4	396.3	384.7	384.9	391.6	403.9	410.4
CH_4	0.3	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.7	1.2	1.1	1.0	1.0	0.9	0.8
HFCs	0.0	1.2	2.5	2.8	3.1	3.4	3.6
Buses	**8.5**	**12.0**	**16.7**	**17.8**	**18.0**	**19.5**	**19.8**
CO_2	8.4	11.7	16.2	17.3	17.5	18.9	19.3
CH_4	+	+	+	+	+	+	+
N_2O	+	+	0.1	0.1	0.1	0.1	0.1
HFCs	0.0	0.3	0.4	0.4	0.4	0.4	0.4
Motorcycles	**1.8**	**1.7**	**3.6**	**4.2**	**4.0**	**3.9**	**3.7**
CO_2	1.7	1.6	3.6	4.1	3.9	3.9	3.7
CH_4	+	+	+	+	+	+	+

[6] In 2007 and 2008 light-duty VMT decreased 3 percent and 2.3 percent, respectively. Note that the decline in light-duty VMT from 2006 to 2007 is due at least in part to a change in FHWA's methods for estimating VMT. In absence of these method changes, light-duty VMT growth between 2006 and 2007 would likely have been higher. See previous footnote.

[7] 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.

[8] See previous footnote.

[9] See previous footnote.

N_2O	+	+	+	+	+	+	+
Commercial	**110.9**	**134.0**	**115.7**	**114.3**	**115.4**	**116.3**	**120.1**
CO_2	109.9	132.7	114.6	113.3	114.3	115.2	119.0
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	1.0	1.2	1.1	1.0	1.1	1.1	1.1
Other Aircraft[c]	**78.3**	**59.7**	**34.2**	**32.1**	**34.7**	**35.2**	**40.6**
CO_2	77.5	59.1	33.9	31.8	34.4	34.9	40.2
CH_4	0.1	0.1	+	+	+	+	+
N_2O	0.7	0.5	0.3	0.3	0.3	0.3	0.4
Ships and Boats[d]	**44.9**	**45.0**	**46.5**	**40.2**	**39.5**	**17.6**	**33.1**
CO_2	44.3	44.3	45.5	39.3	38.7	16.9	32.3
CH_4	+	+	+	+	+	+	+
N_2O	0.6	0.6	0.8	0.7	0.7	0.5	0.6
HFCs	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Rail	**38.9**	**51.3**	**46.6**	**45.6**	**46.7**	**48.5**	**46.7**
CO_2	38.5	50.3	44.7	43.4	44.2	45.7	43.6
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.3	0.4	0.3	0.3	0.3	0.4	0.3
HFCs	0.0	0.5	1.5	1.8	2.1	2.4	2.7
Other Emissions from Electricity Generation[e]	0.1	+	+	+	+	+	+
Pipelines[f]	**36.0**	**32.4**	**38.1**	**40.5**	**46.2**	**39.4**	**38.0**
CO_2	36.0	32.4	38.1	40.5	46.2	39.4	38.0
Lubricants	**11.8**	**10.2**	**9.0**	**8.3**	**8.8**	**9.1**	**10.0**
CO_2	11.8	10.2	9.0	8.3	8.8	9.1	10.0
Total Transportation	**1,554.4**	**2,005.9**	**1,804.3**	**1,784.7**	**1,794.3**	**1,820.0**	**1,810.4**
International Bunker Fuels[g]	*104.5*	*114.2*	*112.8*	*106.8*	*100.7*	*104.2*	*111.8*
Ethanol CO_2[h]	*4.1*	*22.4*	*71.5*	*71.5*	*73.4*	*74.9*	*75.9*
Biodiesel CO_2[h]	*0.0*	*0.9*	*8.3*	*8.5*	*13.5*	*13.3*	*14.1*

+ Does not exceed 0.05 MMT CO_2 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] Consists of emissions from jet fuel consumed by domestic operations of commercial aircraft (no bunkers).

[c] Consists of emissions from jet fuel and aviation gasoline consumption by general aviation and military aircraft.

[d] Fluctuations in emission estimates are associated with fluctuations in reported fuel consumption, and may reflect issues with data sources.

[e] Other emissions from electricity generation are a result of waste incineration (as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants), electrical transmission and distribution, and a portion of Other Process Uses of Carbonates (from pollution control equipment installed in electricity generation plants).

[f] CO_2 estimates reflect natural gas used to power pipelines, but not electricity. While the operation of pipelines produces CH_4 and N_2O, these emissions are not directly attributed to pipelines in the U.S. Inventory.

[g] Emissions from International Bunker Fuels include emissions from both civilian and military activities; these emissions are not included in the transportation totals.

[h] Ethanol and biodiesel CO_2 estimates are presented for informational purposes only. See Section 3.10 and the estimates in Land Use, Land-Use Change, and Forestry (see Chapter 6), in line with IPCC methodological guidance and UNFCCC reporting obligations, for more information on ethanol and biodiesel.

Notes: Passenger cars and light-duty trucks include vehicles typically used for personal travel and less than 8,500 lbs; medium- and heavy-duty trucks include vehicles larger than 8,500 lbs. HFC emissions primarily reflect HFC-134a. Totals may not sum due to independent rounding.

Commercial

The commercial sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Energy-related emissions from the residential and commercial sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. Landfills and wastewater treatment are included in this sector, with landfill emissions decreasing since 1990 and wastewater treatment emissions decreasing slightly.

Residential

The residential sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Emissions from the residential sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. In the long-term, this sector is also affected by population growth, regional migration trends, and changes in housing and building attributes (e.g., size and insulation).

Agriculture

The agriculture end-use sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2015, agricultural soil management was the largest source of N_2O emissions, and enteric fermentation was the largest source of CH_4 emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment like tractors. The agriculture sector is less reliant on electricity than the other sectors.

Box 2-1: Methodology for Aggregating Emissions by Economic Sector

In presenting the Economic Sectors in the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, the Inventory expands upon the standard IPCC sectors common for UNFCCC reporting. Discussing greenhouse gas emissions relevant to U.S.-specific sectors improves communication of the report's findings.

In the Electricity Generation economic sector, CO_2 emissions from the combustion of fossil fuels included in the EIA electric utility fuel consuming sector are apportioned to this economic sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA electric utility sector. Additional sources include CO_2, CH_4, and N_2O from waste incineration, as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants. The Electricity Generation economic sector also includes SF_6 from Electrical Transmission and Distribution, and a portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in electricity generation plants).

In the Transportation economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA transportation fuel consuming sector are apportioned to this economic sector (additional analyses and refinement of the EIA data is further explained in the Energy chapter of this report). Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to this economic sector based on the EIA transportation fuel consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with emissions from transportation refrigeration/air-conditioning systems to this economic sector. Finally, CO_2 emissions from Non-Energy Uses of Fossil Fuels identified as lubricants for transportation vehicles are included in the Transportation economic sector.

For the Industry economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA industrial fuel consuming sector, minus the agricultural use of fuel explained below, are apportioned to this economic sector. The CH_4 and N_2O emissions from stationary and mobile combustion are also apportioned to this economic sector based on the EIA industrial fuel consuming sector, minus emissions apportioned to the Agriculture

economic sector described below. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector. Additionally, all process-related emissions from sources with methods considered within the IPCC IPPU sector have been apportioned to this economic sector. This includes the process-related emissions (i.e., emissions from the actual process to make the material, not from fuels to power the plant) from such activities as Cement Production, Iron and Steel Production and Metallurgical Coke Production, and Ammonia Production. Additionally, fugitive emissions from energy production sources, such as Natural Gas Systems, Coal Mining, and Petroleum Systems are included in the Industry economic sector. A portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in large industrial facilities) are also included in the Industry economic sector. Finally, all remaining CO_2 emissions from Non-Energy Uses of Fossil Fuels are assumed to be industrial in nature (besides the lubricants for transportation vehicles specified above), and are attributed to the Industry economic sector.

As agriculture equipment is included in EIA's industrial fuel consuming sector surveys, additional data is used to extract the fuel used by agricultural equipment, to allow for accurate reporting in the Agriculture economic sector from all sources of emissions, such as motorized farming equipment. Energy consumption estimates are obtained from Department of Agriculture survey data, in combination with separate EIA fuel sales reports. This supplementary data is used to apportion some of the CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion, to the Agriculture economic sector. The other emission sources included in this economic sector are intuitive for the agriculture sectors, such as N_2O emissions from Agricultural Soils, CH_4 from Enteric Fermentation, CH_4 and N_2O from Manure Management, CH_4 from Rice Cultivation, CO_2 emissions from Liming and Urea Application, and CH_4 and N_2O from Forest Fires. Nitrous oxide emissions from the Application of Fertilizers to tree plantations (termed "forest land" by the IPCC) are also included in the Agriculture economic sector.

The Residential economic sector includes the CO_2 emissions from the combustion of fossil fuels reported for the EIA residential sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA residential fuel consuming sector. Substitution of Ozone Depleting Substances are apportioned based on their specific end-uses within the source category, with emissions from residential air-conditioning systems to this economic sector. Nitrous oxide emissions from the Application of Fertilizers to developed land (termed "settlements" by the IPCC) are also included in the Residential economic sector.

The Commercial economic sector includes the CO_2 emissions from the combustion of fossil fuels reported in the EIA commercial fuel consuming sector data. Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to this economic sector based on the EIA transportation fuel consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with emissions from commercial refrigeration/air-conditioning systems apportioned to this economic sector. Public works sources including direct CH_4 from Landfills and CH_4 and N_2O from Wastewater Treatment and Composting are also included in this economic sector.

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

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and 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; or (5) emissions per capita.

Table 2-14 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 Table 2-14 and Figure 2-15). 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

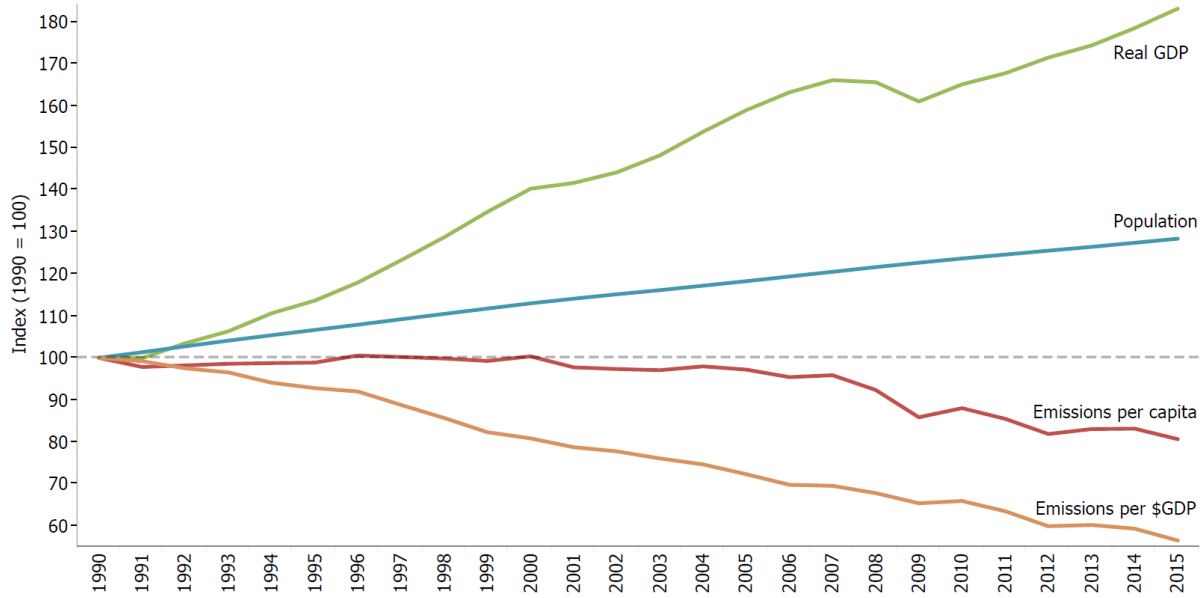
2005. Total energy and fossil fuel consumption have also decreased at slower rates than emissions since 2005, while electricity consumption, GDP, and national population continued to increase.

Table 2-14: Recent Trends in Various U.S. Data (Index 1990 = 100)

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

[a] Average annual growth rate
[b] GWP-weighted values
[c] Energy-content-weighted values (EIA 2017)
[d] Gross Domestic Product in chained 2009 dollars (BEA 2017)
[e] U.S. Census Bureau (2016)

Figure 2-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product



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

2.3 Indirect Greenhouse Gas Emissions (CO, NO_x, NMVOCs, and SO_2)

The reporting requirements of the UNFCCC[10] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases. Carbon monoxide is produced when carbon-containing fuels are combusted incompletely. Nitrogen oxides (i.e., NO and NO_2) are created by lightning, fires, fossil fuel combustion, and in the stratosphere from N_2O. Non-methane volatile organic compounds—which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane, and many others)—are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. In the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling) and therefore are discussed separately.

One important indirect climate change effect of NMVOCs and NO_x is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other greenhouse gases. Another example of indirect greenhouse gas formation into greenhouse gases is the interaction of CO with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2015),[11] which are regulated under the Clean Air Act. Table 2-15 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Table 2-15: Emissions of NO_x, CO, NMVOCs, and SO_2 (kt)

Gas/Activity	1990	2005	2011	2012	2013	2014	2015
NO_x	**21,790**	**17,443**	**12,482**	**12,038**	**11,387**	**10,810**	**9,971**
Mobile Fossil Fuel Combustion	10,862	10,295	7,294	6,871	6,448	6,024	5,417
Stationary Fossil Fuel Combustion	10,023	5,858	3,807	3,655	3,504	3,291	3,061
Oil and Gas Activities	139	321	622	663	704	745	745
Industrial Processes and Product Use	592	572	452	443	434	424	424
Forest Fires	80	239	172	276	185	188	188
Waste Combustion	82	128	73	82	91	100	100
Grassland Fires	5	21	54	39	13	27	27
Agricultural Burning	6	6	7	7	7	8	8
Waste	+	2	1	2	2	2	2
CO	**132,877**	**75,570**	**52,586**	**54,119**	**48,620**	**46,922**	**44,954**
Mobile Fossil Fuel Combustion	119,360	58,615	38,305	36,153	34,000	31,848	29,881
Forest Fires	2,832	8,486	6,136	9,815	6,655	6,642	6,642
Stationary Fossil Fuel Combustion	5,000	4,648	4,170	4,027	3,884	3,741	3,741
Waste Combustion	978	1,403	1,003	1,318	1,632	1,947	1,947
Industrial Processes and Product Use	4,129	1,557	1,229	1,246	1,262	1,273	1,273
Oil and Gas Activities	302	318	610	666	723	780	780

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

[11] NO_x and CO emission estimates from Field Burning of Agricultural Residues were estimated separately, and therefore not taken from EPA (2016b).

Grassland Fires	84	358	894	657	217	442	442
Agricultural Burning	191	178	234	232	239	240	239
Waste	1	7	5	6	8	9	9
NMVOCs	**20,930**	**13,154**	**11,726**	**11,464**	**11,202**	**10,935**	**10,647**
Industrial Processes and Product Use	7,638	5,849	3,929	3,861	3,793	3,723	3,723
Mobile Fossil Fuel Combustion	10,932	5,724	4,562	4,243	3,924	3,605	3,318
Oil and Gas Activities	554	510	2,517	2,651	2,786	2,921	2,921
Stationary Fossil Fuel Combustion	912	716	599	569	539	507	507
Waste Combustion	222	241	81	94	108	121	121
Waste	673	114	38	45	51	57	57
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**5,877**	**5,876**	**5,874**	**4,357**	**3,448**
Stationary Fossil Fuel Combustion	18,407	11,541	5,008	5,006	5,005	3,640	2,756
Industrial Processes and Product Use	1,307	831	604	604	604	496	496
Mobile Fossil Fuel Combustion	390	180	108	108	108	93	93
Oil and Gas Activities	793	619	142	142	142	95	70
Waste Combustion	38	25	15	15	15	32	32
Waste	+	1	+	+	+	1	1
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

+ Does not exceed 0.5 kt.
NA (Not Available)
Note: Totals may not sum due to independent rounding.
Source: (EPA 2015) except for estimates from Field Burning of Agricultural Residues.

Box 2-3: Sources and Effects of Sulfur Dioxide

Sulfur dioxide (SO_2) emitted into the atmosphere through natural and anthropogenic processes affects the earth's radiative budget through its photochemical transformation into sulfate aerosols that can (1) scatter radiation from the sun back to space, thereby reducing the radiation reaching the earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., by providing surfaces for heterogeneous chemical reactions). The indirect effect of sulfur-derived aerosols on radiative forcing can be considered in two parts. The first indirect effect is the aerosols' tendency to decrease water droplet size and increase water droplet concentration in the atmosphere. The second indirect effect is the tendency of the reduction in cloud droplet size to affect precipitation by increasing cloud lifetime and thickness. Although still highly uncertain the radiative forcing estimates from both the first and the second indirect effect are believed to be negative, as is the combined radiative forcing of the two (IPCC 2013).

Sulfur dioxide is also a major contributor to the formation of regional haze, which can cause significant increases in acute and chronic respiratory diseases. Once SO_2 is emitted, it is chemically transformed in the atmosphere and returns to the earth as the primary source of acid rain. Because of these harmful effects, the United States has regulated SO_2 emissions in the Clean Air Act.

Electricity generation is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 59.2 percent in 2015. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high-sulfur to low-sulfur coal and installing flue gas desulfurization equipment.