2. Trends in Greenhouse Gas Emissions

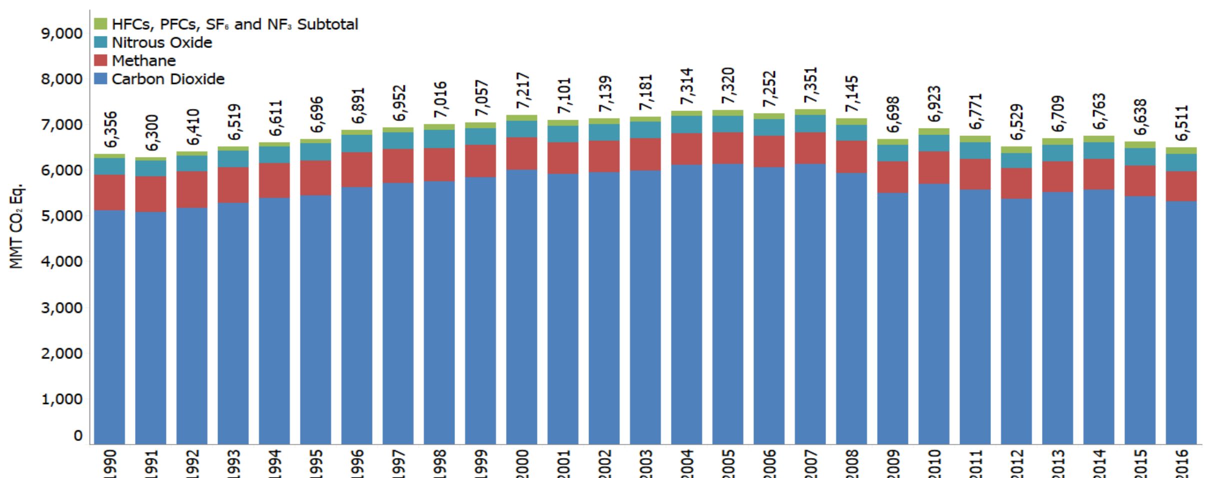
2.1 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2016, total gross U.S. greenhouse gas emissions were 6,511.3 MMT, or million metric tons, carbon dioxide (CO_2) Eq. [1] Total U.S. emissions have increased by 2.4 percent from 1990 to 2016, and emissions decreased from 2015 to 2016 by 1.9 percent (126.8 MMT CO_2 Eq.). The decrease in total greenhouse gas emissions between 2015 and 2016 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 and other non-fossil energy sources in the electric power sector; and
(2) warmer winter conditions in 2016 resulting in a decreased demand for heating fuel in the residential and commercial sectors.

Since 1990, U.S. emissions have increased at an average annual rate of 0.1 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 2016 were 12.1 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.)



[1] The gross emissions total presented in this report for the United States excludes emissions and removals from Land Use, Land-Use Change, and Forestry (LULUCF). The net emissions total presented in this report for the United States includes emissions and removals from LULUCF.

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

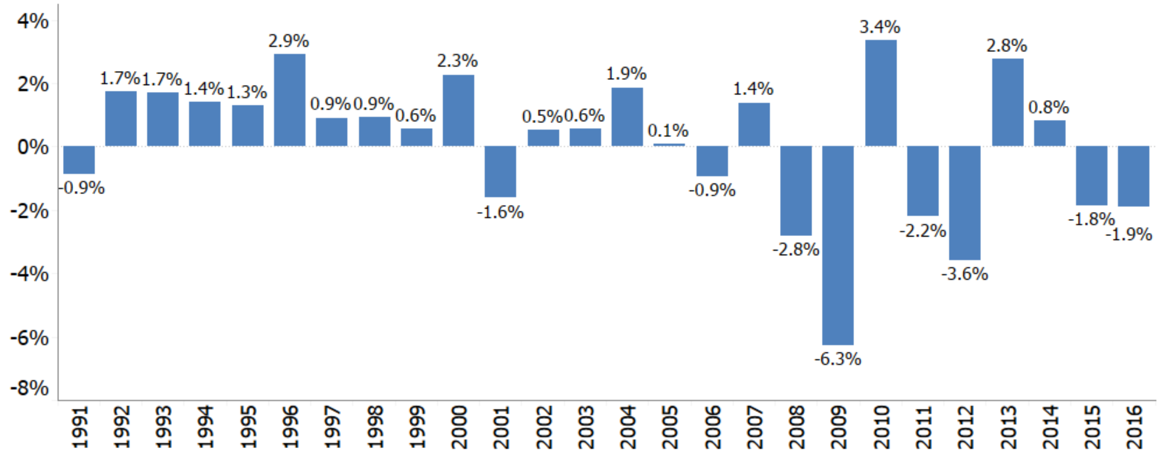
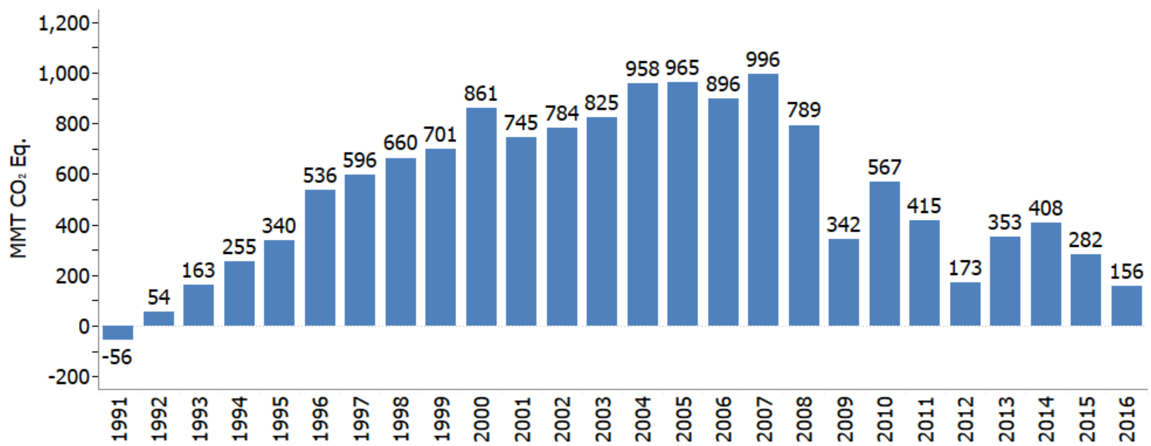


Figure 2-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)



Overall, from 1990 to 2016, total emissions of CO_2 increased by 189.6 MMT CO_2 Eq. (3.7 percent), while total emissions of methane (CH_4) decreased by 122.5 MMT CO_2 Eq. (15.7 percent), and total emissions of nitrous oxide (N_2O) increased by 14.8 MMT CO_2 Eq. (4.2 percent). During the same period, aggregate weighted emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) rose by 73.8 MMT CO_2 Eq. (74.0 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 11.5 percent of total emissions in 2016.

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	2012	2013	2014	2015	2016
CO_2	**5,121.3**	**6,132.0**	**5,366.7**	**5,519.6**	**5,568.8**	**5,420.8**	**5,310.9**
Fossil Fuel Combustion	4,740.3	5,746.9	5,024.4	5,156.9	5,200.3	5,049.3	4,966.0
Electric Power	*1,820.8*	*2,400.9*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*	*1,809.3*
Transportation	*1,467.6*	*1,855.8*	*1,661.9*	*1,677.6*	*1,717.1*	*1,735.5*	*1,782.6*
Industrial	*858.8*	*855.7*	*812.9*	*843.3*	*824.9*	*809.5*	*809.1*
Residential	*338.3*	*357.8*	*282.5*	*329.7*	*345.3*	*316.8*	*292.5*
Commercial	*227.2*	*227.0*	*201.3*	*225.7*	*233.6*	*245.4*	*231.3*
U.S. Territories	*27.6*	*49.7*	*43.5*	*42.5*	*41.4*	*41.4*	*41.4*
Non-Energy Use of Fuels	119.5	138.9	108.0	123.5	118.9	125.6	112.2
Iron and Steel Production & Metallurgical Coke Production	101.6	68.2	55.6	53.5	58.4	47.8	42.3
Cement Production	33.5	46.2	35.3	36.4	39.4	39.9	39.4
Petrochemical Production	21.2	26.8	26.5	26.4	26.5	28.1	28.1
Natural Gas Systems	29.8	22.5	23.3	24.8	25.3	24.9	25.5
Petroleum Systems	7.7	11.7	19.3	22.6	26.3	28.8	22.8
Lime Production	11.7	14.6	13.8	14.0	14.2	13.3	12.9
Ammonia Production	13.0	9.2	9.4	10.0	9.6	10.9	12.2
Other Process Uses of Carbonates	6.3	7.6	9.1	11.5	13.0	12.3	11.0
Incineration of Waste	8.0	12.5	10.4	10.4	10.6	10.7	10.7
Urea Fertilization	2.4	3.5	4.3	4.4	4.5	4.9	5.1
Carbon Dioxide Consumption	1.5	1.4	4.0	4.2	4.5	4.5	4.5
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.4	4.1	1.5	4.2	4.0
Liming	4.7	4.3	6.0	3.9	3.6	3.8	3.9
Ferroalloy Production	2.2	1.4	1.9	1.8	1.9	2.0	1.8
Soda Ash Production	1.4	1.7	1.7	1.7	1.7	1.7	1.7
Titanium Dioxide Production	1.2	1.8	1.5	1.7	1.7	1.6	1.6
Aluminum Production	6.8	4.1	3.4	3.3	2.8	2.8	1.3
Glass Production	1.5	1.9	1.2	1.3	1.3	1.3	1.2
Phosphoric Acid Production	1.5	1.3	1.1	1.1	1.0	1.0	1.0
Zinc Production	0.6	1.0	1.5	1.4	1.0	0.9	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
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Magnesium Production and Processing	+	+	+	+	+	+	+
Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*219.4*	*230.7*	*287.7*	*316.4*	*324.3*	*310.4*	*309.3*
International Bunker Fuels[b]	*103.5*	*113.1*	*105.8*	*99.8*	*103.4*	*110.9*	*116.6*
CH_4[c]	**779.9**	**688.6**	**662.5**	**662.6**	**664.0**	**665.4**	**657.4**
Enteric Fermentation	164.2	168.9	166.7	165.5	164.2	166.5	170.1
Natural Gas Systems	195.2	169.1	159.6	163.8	164.3	166.3	163.5
Landfills	179.6	132.7	117.0	113.3	112.7	111.7	107.7
Manure Management	37.2	56.3	65.6	63.3	62.9	66.3	67.7
Coal Mining	96.5	64.1	66.5	64.6	64.6	61.2	53.8
Petroleum Systems	39.8	32.1	32.7	36.6	38.6	38.1	38.6
Wastewater Treatment	15.7	15.8	15.1	14.9	15.0	15.1	14.8
Rice Cultivation	16.0	16.7	11.3	11.5	12.7	12.3	13.7
Stationary Combustion	8.6	7.8	7.4	8.8	8.9	7.9	7.3
Abandoned Oil and Gas Wells	6.5	6.9	7.0	7.0	7.1	7.2	7.1
Abandoned Underground Coal Mines	7.2	6.6	6.2	6.2	6.3	6.4	6.7
Mobile Combustion	12.7	9.4	5.1	4.7	4.2	3.8	3.6
Composting	0.4	1.9	1.9	2.0	2.1	2.1	2.1

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	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O[c]	**354.8**	**357.8**	**335.8**	**363.2**	**361.2**	**379.6**	**369.5**
Agricultural Soil Management	250.5	253.5	247.9	276.6	274.0	295.0	283.6
Stationary Combustion	11.1	17.5	16.9	18.7	19.0	18.1	18.6
Mobile Combustion	41.7	38.8	24.3	22.5	20.6	19.3	18.4
Manure Management	14.0	16.5	17.5	17.5	17.5	17.7	18.1
Nitric Acid Production	12.1	11.3	10.5	10.7	10.9	11.6	10.2
Adipic Acid Production	15.2	7.1	5.5	3.9	5.4	4.3	7.0
Wastewater Treatment	3.4	4.4	4.6	4.7	4.8	4.8	5.0
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	2.0	2.0	2.0	2.0	2.0
Composting	0.3	1.7	1.7	1.8	1.9	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[b]	*0.9*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*	*1.0*
HFCs	**46.6**	**123.0**	**150.5**	**151.1**	**156.7**	**160.8**	**162.3**
Substitution of Ozone Depleting Substances[d]	0.3	102.7	144.8	146.8	151.3	156.1	159.1
HCFC-22 Production	46.1	20.0	5.5	4.1	5.0	4.3	2.8
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	0.1	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**5.9**	**5.8**	**5.6**	**5.1**	**4.3**
Semiconductor Manufacture	2.8	3.3	3.0	2.8	3.1	3.1	3.0
Aluminum Production	21.5	3.4	2.9	3.0	2.5	2.0	1.4
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF_6	**28.8**	**11.8**	**6.7**	**6.3**	**6.4**	**5.9**	**6.2**
Electrical Transmission and Distribution	23.1	8.3	4.7	4.5	4.7	4.3	4.3
Magnesium Production and Processing	5.2	2.7	1.6	1.5	1.0	0.9	1.0
Semiconductor Manufacture	0.5	0.7	0.3	0.4	0.7	0.7	0.8
NF_3	**+**	**0.5**	**0.6**	**0.6**	**0.5**	**0.6**	**0.6**
Semiconductor Manufacture	+	0.5	0.6	0.6	0.5	0.6	0.6
Total Emissions	**6,355.6**	**7,320.3**	**6,528.8**	**6,709.1**	**6,763.1**	**6,638.1**	**6,511.3**
LULUCF Emissions[c]	**10.6**	**23.0**	**26.1**	**19.2**	**19.6**	**38.2**	**38.1**
LULUCF CH_4 Emissions	6.7	13.3	15.0	10.9	11.2	22.4	22.4
LULUCF N_2O Emissions	3.9	9.7	11.1	8.3	8.4	15.8	15.7
LULUCF Carbon Stock Change[e]	**(830.2)**	**(754.2)**	**(779.5)**	**(755.0)**	**(760.0)**	**(733.4)**	**(754.9)**
LULUCF Sector Net Total[f]	**(819.6)**	**(731.1)**	**(753.5)**	**(735.8)**	**(740.4)**	**(695.2)**	**(716.8)**
Net Emissions (Sources and Sinks)	**5,536.0**	**6,589.1**	**5,775.3**	**5,973.3**	**6,022.8**	**5,942.9**	**5,794.5**

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] 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.

[b] Emissions from International Bunker Fuels are not included in totals.
[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals. 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. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.
[d] Small amounts of PFC emissions also result from this source.
[e] 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.
[f] 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	2012	2013	2014	2015	2016
CO_2	**5,121,264**	**6,132,006**	**5,366,730**	**5,519,613**	**5,568,759**	**5,420,804**	**5,310,861**
Fossil Fuel Combustion	4,740,344	5,746,942	5,024,373	5,156,898	5,200,297	5,049,254	4,966,049
Electric Power	*1,820,818*	*2,400,874*	*2,022,181*	*2,038,122*	*2,038,018*	*1,900,673*	*1,809,252*
Transportation	*1,467,564*	*1,855,751*	*1,661,895*	*1,677,593*	*1,717,132*	*1,735,469*	*1,782,585*
Industrial	*858,840*	*855,719*	*812,945*	*843,252*	*824,929*	*809,495*	*809,062*
Residential	*338,347*	*357,834*	*282,501*	*329,742*	*345,296*	*316,821*	*292,501*
Commercial	*227,219*	*227,041*	*201,325*	*225,722*	*233,557*	*245,416*	*231,269*
U.S. Territories	*27,555*	*49,723*	*43,527*	*42,467*	*41,365*	*41,380*	*41,380*
Non-Energy Use of Fuels	119,546	138,885	107,987	123,485	118,877	125,634	112,199
Iron and Steel Production & Metallurgical Coke Production	101,630	68,210	55,600	53,471	58,353	47,825	42,306
Cement Production	33,484	46,194	35,270	36,369	39,439	39,907	39,439
Petrochemical Production	21,203	26,794	26,501	26,395	26,496	28,062	28,110
Natural Gas Systems	29,831	22,512	23,276	24,827	25,336	24,888	25,516
Petroleum Systems	7,689	11,700	19,300	22,611	26,324	28,752	22,767
Lime Production	11,700	14,552	13,785	14,028	14,210	13,342	12,942
Ammonia Production	13,047	9,196	9,377	9,962	9,619	10,883	12,194
Other Process Uses of Carbonates	6,297	7,644	9,119	11,524	12,954	12,312	10,986
Incineration of Waste	7,950	12,469	10,392	10,361	10,604	10,670	10,676
Urea Fertilization	2,417	3,504	4,282	4,443	4,538	4,888	5,098
Carbon Dioxide Consumption	1,472	1,375	4,019	4,188	4,471	4,471	4,471
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	4,392	4,074	1,541	4,169	3,959
Liming	4,667	4,349	5,978	3,907	3,609	3,777	3,863
Ferroalloy Production	2,152	1,392	1,903	1,785	1,914	1,960	1,796
Soda Ash Production	1,431	1,655	1,665	1,694	1,685	1,714	1,723
Titanium Dioxide Production	1,195	1,755	1,528	1,715	1,688	1,635	1,608
Aluminum Production	6,831	4,142	3,439	3,255	2,833	2,767	1,334
Glass Production	1,535	1,928	1,248	1,317	1,336	1,299	1,243
Phosphoric Acid Production	1,529	1,342	1,118	1,149	1,038	999	992
Zinc Production	632	1,030	1,486	1,429	956	933	925
Lead Production	516	553	527	546	459	473	482
Silicon Carbide Production and Consumption	375	219	158	169	173	180	174
Abandoned Oil and Gas Wells	6	7	7	7	7	7	7
Magnesium Production and Processing	1	3	2	2	2	3	3

Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*219,413*	*230,700*	*287,732*	*316,405*	*324,308*	*310,430*	*309,252*
International Bunker Fuels[b]	*103,463*	*113,139*	*105,805*	*99,763*	*103,400*	*110,887*	*116,594*
CH_4[c]	**31,198**	**27,544**	**26,500**	**26,502**	**26,558**	**26,615**	**26,298**
Enteric Fermentation	6,566	6,755	6,670	6,619	6,567	6,661	6,805
Natural Gas Systems	7,806	6,765	6,384	6,553	6,572	6,651	6,541
Landfills	7,182	5,310	4,680	4,531	4,509	4,467	4,306
Manure Management	1,486	2,254	2,625	2,530	2,514	2,651	2,709
Coal Mining	3,860	2,565	2,658	2,584	2,583	2,449	2,153
Petroleum Systems	1,592	1,284	1,307	1,463	1,543	1,523	1,544
Wastewater Treatment	627	631	604	596	598	605	593
Rice Cultivation	641	667	453	462	510	493	549
Stationary Combustion	345	313	295	351	356	317	293
Abandoned Oil and Gas Wells	260	275	279	280	282	286	284
Abandoned Underground Coal Mines	288	264	249	249	253	256	268
Mobile Combustion	508	374	204	188	170	152	146
Composting	15	75	77	81	84	84	85
Field Burning of Agricultural Residues	9	8	11	11	11	11	11
Petrochemical Production	9	3	3	3	5	7	10
Ferroalloy Production	1	+	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[b]	*7*	*5*	*4*	*3*	*3*	*3*	*4*
N_2O[c]	**1,190**	**1,201**	**1,127**	**1,219**	**1,212**	**1,274**	**1,240**
Agricultural Soil Management	840	851	832	928	920	990	952
Stationary Combustion	37	59	57	63	64	61	62
Mobile Combustion	140	130	81	75	69	65	62
Manure Management	47	55	59	59	59	59	61
Nitric Acid Production	41	38	35	36	37	39	34
Adipic Acid Production	51	24	19	13	18	14	23
Wastewater Treatment	11	15	16	16	16	16	17
N_2O from Product Uses	14	14	14	14	14	14	14
Caprolactam, Glyoxal, and Glyoxylic Acid Production	6	7	7	7	7	7	7
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[b]	*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	+	+	+	+	+
Semiconductor Manufacture	M	M	M	M	M	M	M
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] 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.
[b] Emissions from International Bunker Fuels are not included in totals.
[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.
[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-seven-year period of 1990 to 2016, total emissions from the Energy, Industrial Processes and Product Use, and Agriculture sectors grew by 130.1 MMT CO_2 Eq. (2.4 percent), 20.0 MMT CO_2 Eq. (5.9 percent), and 73.4 MMT CO_2 Eq. (15.0 percent), respectively. Emissions from the Waste sector decreased by 67.9 MMT CO_2 Eq. (34.1 percent). Over the same period, total C sequestration in the Land Use, Land-Use Change, and Forestry (LULUCF) sector decreased by 75.4 MMT CO_2 (9.1 percent decrease in total C sequestration), and emissions from the LULUCF sector increased by 27.4 MMT CO_2 Eq. (258 percent).

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

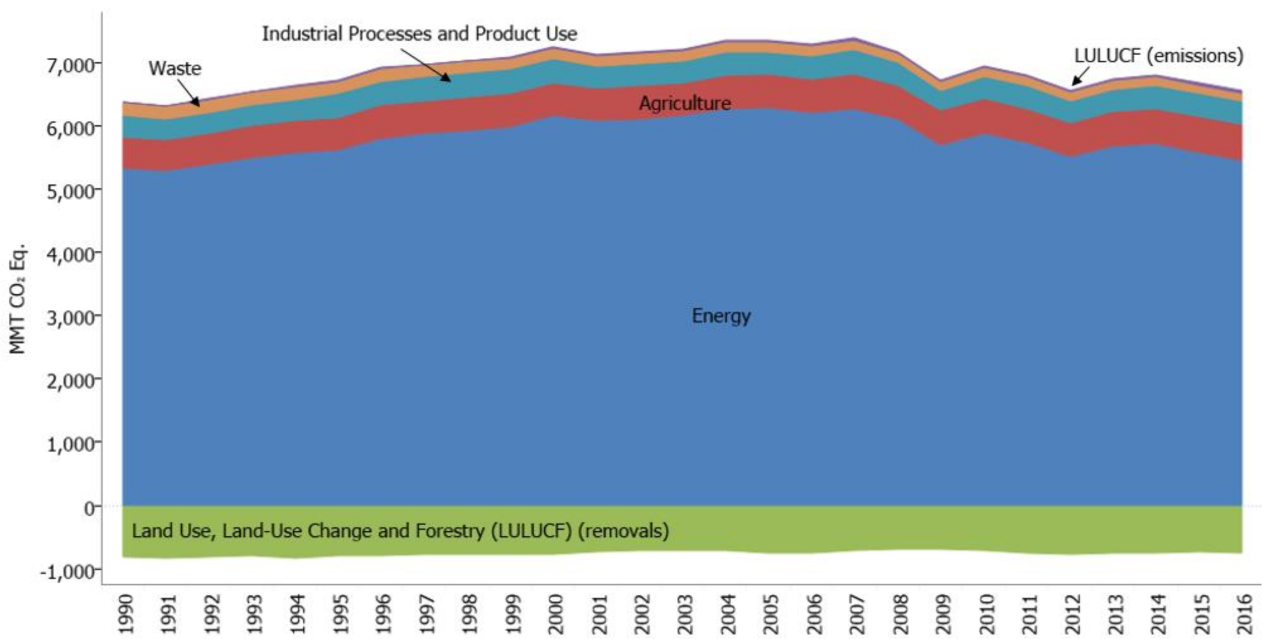


Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

Chapter/IPCC Sector	1990		2005		2012	2013	2014	2015	2016
Energy	**5,325.1**		**6,285.2**		**5,511.2**	**5,671.4**	**5,715.4**	**5,567.8**	**5,455.2**

Fossil Fuel Combustion	4,740.3	5,746.9	5,024.4	5,156.9	5,200.3	5,049.3	4,966.0
Natural Gas Systems	225.0	191.6	182.9	188.6	189.6	191.2	189.0
Non-Energy Use of Fuels	119.5	138.9	108.0	123.5	118.9	125.6	112.2
Petroleum Systems	47.5	43.8	52.0	59.2	64.9	66.8	61.4
Coal Mining	96.5	64.1	66.5	64.6	64.6	61.2	53.8
Stationary Combustion	19.7	25.3	24.3	27.5	28.0	26.1	25.9
Mobile Combustion	54.4	48.2	29.4	27.2	24.9	23.1	22.0
Incineration of Waste	8.4	12.9	10.7	10.7	10.9	11.0	11.0
Abandoned Oil and Gas Wells	6.5	6.9	7.0	7.0	7.1	7.2	7.1
Abandoned Underground Coal Mines	7.2	6.6	6.2	6.2	6.3	6.4	6.7
Industrial Processes and Product Use	**342.0**	**358.6**	**357.4**	**357.9**	**371.4**	**367.8**	**362.1**
Substitution of Ozone Depleting Substances	0.3	102.7	144.9	146.8	151.3	156.1	159.1
Iron and Steel Production & Metallurgical Coke Production	101.7	68.2	55.6	53.5	58.4	47.8	42.3
Cement Production	33.5	46.2	35.3	36.4	39.4	39.9	39.4
Petrochemical Production	21.4	26.9	26.6	26.5	26.6	28.2	28.4
Lime Production	11.7	14.6	13.8	14.0	14.2	13.3	12.9
Ammonia Production	13.0	9.2	9.4	10.0	9.6	10.9	12.2
Other Process Uses of Carbonates	6.3	7.6	9.1	11.5	13.0	12.3	11.0
Nitric Acid Production	12.1	11.3	10.5	10.7	10.9	11.6	10.2
Adipic Acid Production	15.2	7.1	5.5	3.9	5.4	4.3	7.0
Semiconductor Manufacture	3.6	4.7	4.4	4.0	4.9	5.0	5.0
Carbon Dioxide Consumption	1.5	1.4	4.0	4.2	4.5	4.5	4.5
Electrical Transmission and Distribution	23.1	8.3	4.7	4.5	4.7	4.3	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.4	4.1	1.5	4.2	4.0
HCFC-22 Production	46.1	20.0	5.5	4.1	5.0	4.3	2.8
Aluminum Production	28.3	7.6	6.4	6.2	5.4	4.8	2.7
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	2.0	2.0	2.0	2.0	2.0
Ferroalloy Production	2.2	1.4	1.9	1.8	1.9	2.0	1.8
Soda Ash Production	1.4	1.7	1.7	1.7	1.7	1.7	1.7
Titanium Dioxide Production	1.2	1.8	1.5	1.7	1.7	1.6	1.6
Glass Production	1.5	1.9	1.2	1.3	1.3	1.3	1.2
Magnesium Production and Processing	5.2	2.7	1.7	1.5	1.1	1.0	1.1
Phosphoric Acid Production	1.5	1.3	1.1	1.1	1.0	1.0	1.0
Zinc Production	0.6	1.0	1.5	1.4	1.0	0.9	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	**489.2**	**520.0**	**519.8**	**543.1**	**539.8**	**566.9**	**562.6**
Agricultural Soil Management	250.5	253.5	247.9	276.6	274.0	295.0	283.6
Enteric Fermentation	164.2	168.9	166.7	165.5	164.2	166.5	170.1
Manure Management	51.1	72.9	83.2	80.8	80.4	84.0	85.9
Rice Cultivation	16.0	16.7	11.3	11.5	12.7	12.3	13.7
Urea Fertilization	2.4	3.5	4.3	4.4	4.5	4.9	5.1
Liming	4.7	4.3	6.0	3.9	3.6	3.8	3.9
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Waste	**199.3**	**156.4**	**140.4**	**136.7**	**136.5**	**135.6**	**131.5**
Landfills	179.6	132.7	117.0	113.3	112.7	111.7	107.7
Wastewater Treatment	19.1	20.2	19.7	19.6	19.8	20.0	19.8
Composting	0.7	3.5	3.7	3.9	4.0	4.0	4.0
Total Emissions[a]	**6,355.6**	**7,320.3**	**6,528.8**	**6,709.1**	**6,763.1**	**6,638.1**	**6,511.3**

Land Use, Land-Use Change, and Forestry	**(819.6)**	**(731.1)**	**(753.5)**	**(735.8)**	**(740.4)**	**(695.2)**	**(716.8)**
Forest land	(784.3)	(730.0)	(723.3)	(733.3)	(731.7)	(709.9)	(714.2)
Cropland	2.4	(0.7)	1.3	11.9	11.2	16.8	13.8
Grassland	13.8	25.3	0.8	18.5	14.7	33.6	21.0
Wetlands	(4.0)	(5.3)	(4.1)	(4.1)	(4.1)	(4.1)	(4.2)
Settlements	(47.6)	(20.5)	(28.3)	(28.8)	(30.5)	(31.5)	(33.2)
Net Emission (Sources and Sinks)[b]	**5,536.0**	**6,589.1**	**5,775.3**	**5,973.3**	**6,022.8**	**5,942.9**	**5,794.5**

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.

[a] Total emissions without LULUCF.

[b] Net emissions with LULUCF.

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 2016. Fossil fuel combustion is the largest source 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 2016, approximately 81 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 19 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 use is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (43 percent and 10 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: 2016 Energy Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

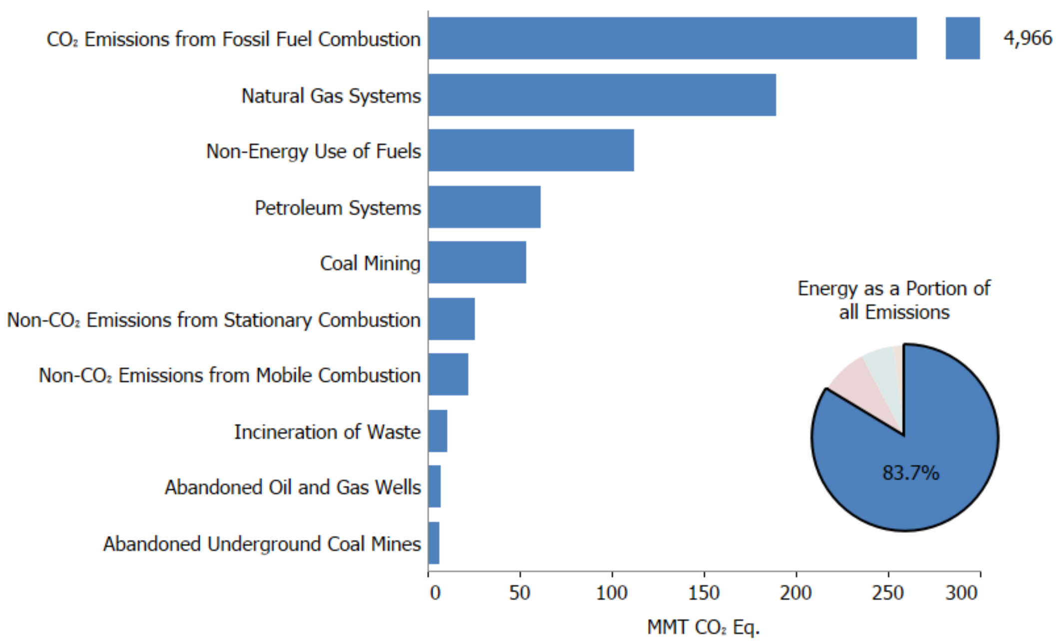


Figure 2-6: 2016 U.S. Fossil Carbon Flows (MMT CO_2 Eq.)

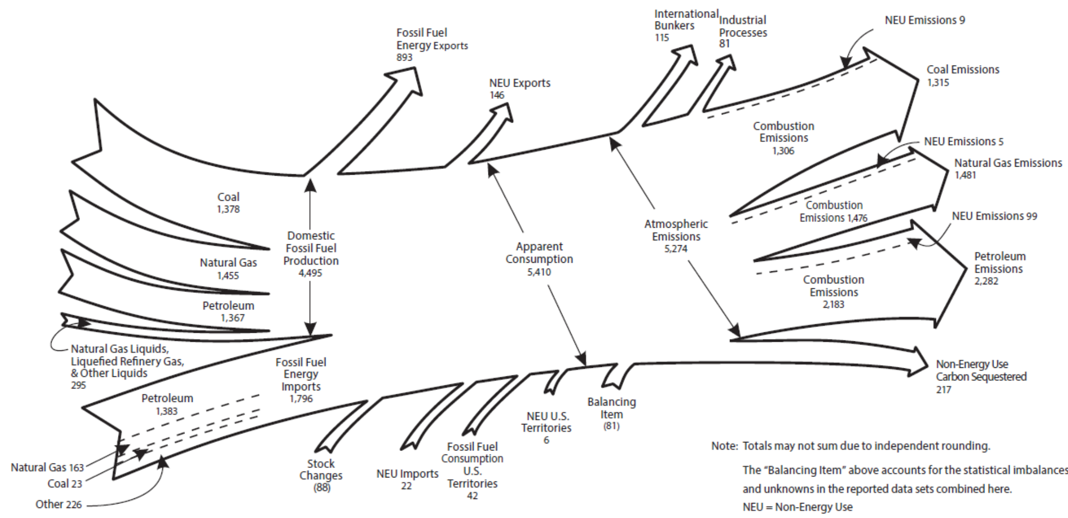


Table 2-4: Emissions from Energy (MMT CO_2 Eq.)

Gas/Source	1990	2005	2012	2013	2014	2015	2016
CO_2	**4,905.4**	**5,932.5**	**5,185.3**	**5,338.2**	**5,381.4**	**5,239.2**	**5,137.2**
Fossil Fuel Combustion	4,740.3	5,746.9	5,024.4	5,156.9	5,200.3	5,049.3	4,966.0
Electric Power	*1,820.8*	*2,400.9*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*	*1,809.3*
Transportation	*1,467.6*	*1,855.8*	*1,661.9*	*1,677.6*	*1,717.1*	*1,735.5*	*1,782.6*
Industrial	*858.8*	*855.7*	*812.9*	*843.3*	*824.9*	*809.5*	*809.1*
Residential	*338.3*	*357.8*	*282.5*	*329.7*	*345.3*	*316.8*	*292.5*
Commercial	*227.2*	*227.0*	*201.3*	*225.7*	*233.6*	*245.4*	*231.3*
U.S. Territories	*27.6*	*49.7*	*43.5*	*42.5*	*41.4*	*41.4*	*41.4*
Non-Energy Use of Fuels	119.5	138.9	108.0	123.5	118.9	125.6	112.2
Natural Gas Systems	29.8	22.5	23.3	24.8	25.3	24.9	25.5
Petroleum Systems	7.7	11.7	19.3	22.6	26.3	28.8	22.8
Incineration of Waste	8.0	12.5	10.4	10.4	10.6	10.7	10.7
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Biomass-Wood[a]	*215.2*	*206.9*	*206.4*	*228.2*	*234.9*	*217.4*	*208.4*
International Bunker Fuels[b]	*103.5*	*113.1*	*105.8*	*99.8*	*103.4*	*110.9*	*116.6*
Biofuels-Ethanol[a]	*4.2*	*22.9*	*72.8*	*74.7*	*76.1*	*78.9*	*81.2*
Biofuels-Biodiesel[a]	*0.0*	*0.9*	*8.5*	*13.5*	*13.3*	*14.1*	*19.6*
CH_4	**366.5**	**296.0**	**284.4**	**291.7**	**294.0**	**290.9**	**280.7**
Natural Gas Systems	195.2	169.1	159.6	163.8	164.3	166.3	163.5
Coal Mining	96.5	64.1	66.5	64.6	64.6	61.2	53.8
Petroleum Systems	39.8	32.1	32.7	36.6	38.6	38.1	38.6
Stationary Combustion	8.6	7.8	7.4	8.8	8.9	7.9	7.3
Abandoned Oil and Gas Wells	6.5	6.9	7.0	7.0	7.1	7.2	7.1
Abandoned Underground Coal Mines	7.2	6.6	6.2	6.2	6.3	6.4	6.7
Mobile Combustion	12.7	9.4	5.1	4.7	4.2	3.8	3.6
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**53.2**	**56.7**	**41.5**	**41.5**	**40.0**	**37.7**	**37.3**
Stationary Combustion	11.1	17.5	16.9	18.7	19.0	18.1	18.6
Mobile Combustion	41.7	38.8	24.3	22.5	20.6	19.3	18.4
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
International Bunker Fuels[b]	*0.9*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*	*1.0*
Total	**5,325.1**	**6,285.2**	**5,511.2**	**5,671.4**	**5,715.4**	**5,567.8**	**5,455.2**

+ Does not exceed 0.05 MMT CO_2 Eq.
[a] 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.
[b] Emissions from International Bunker Fuels are not included in totals.
Note: Totals may not sum due to independent rounding.

CO_2 Emissions from Fossil Fuel Combustion

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 4.8 percent (225.7 MMT CO_2 Eq.) from 1990 to 2016 and were responsible for most of the increase in national emissions during this period. Conversely, CO_2 emissions from fossil fuel combustion decreased from 2005 levels by 780.9 MMT CO_2 Eq., a decrease of approximately 13.6 percent between 2005 and 2016. From 2015 to 2016, these emissions decreased by 1.6 percent (83.2 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 electric power is influenced by a number of factors including the relative price of coal and alternative sources, the ability to switch fuels, and longer term 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 consumption.

Energy-related CO_2 emissions also depend on the type of fuel consumed or energy used 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-40 in Annex 2.1 for more detail on the C Content Coefficient of different fossil fuels).

Trends in CO_2 emissions from fossil fuel combustion over the past decade have been strongly influenced by the electric power sector, which historically has accounted for the largest share of emissions from this source (see Figure 2-7). In recent years, the types of fuel consumed to produce electricity have changed. Carbon dioxide emissions from coal consumption for electric power generation decreased by 36.6 percent since 2008, and there has been a shift to the use of less-CO_2-intensive natural gas to supply electricity. There has also been a rapid increase in renewable energy capacity additions in the electric power sector in recent years. In 2016, renewable energy sources accounted for 63 percent of capacity additions with natural gas accounting for the majority of the remaining additions. The share of renewable energy capacity additions has grown significantly since 2010, when renewable energy sources accounted for only 28 percent of total capacity additions (EIA 2017c). Electricity generation from renewable sources increased by 14 percent from 2015 to 2016. The decrease in coal-powered electricity generation and increase in renewable energy electricity generation have contributed to a 4.8 percent decrease in emissions from electric power generation from 2015 to 2016 (see Figure 2-9), and lower CO_2 emissions from fossil fuel combustion over the time series (i.e., 1990 through 2016).

Total petroleum use is another major driver of CO_2 emissions from fossil fuel combustion, particularly in the transportation sector, which represents the second largest source of CO_2 emissions from fossil fuel combustion. Emissions from petroleum consumption for transportation have increased by 21.7 percent since 1990, which can be primarily attributed to a 48.0 percent increase in vehicle miles traveled (VMT) over the time series. Fuel economy of light-duty vehicles is another important factor. The decline in new light-duty vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light-duty trucks, which grew from about 30 percent of new vehicle sales in 1990 to 48 percent in 2004. Since 2005, average new vehicle fuel economy has increased while the market share of light-duty trucks has decreased. Total transportation sector CO_2 emissions have increased by 5.2 percent since 2010.

The overall trends in CO_2 emissions from fossil fuel combustion in the residential and commercial sectors closely align with heating degree days. Emissions from the residential and commercial sectors decreased by 7.7 percent and 5.8 percent from 2015 to 2016, respectively. This trend can be largely attributed to a 5 percent decrease in heating degree days which led to a decreased demand for heating fuel and electricity for heat in the residential and commercial sectors. In addition, an increase in energy efficiency standards and the use of energy efficient products in residential and commercial buildings has resulted in an overall reduction in energy use, contributing to a decrease in emissions in both of these sectors (EIA 2017a). Combined residential and commercial sector emissions have decreased by 6.5 percent since 2010.

The increase in transportation sector petroleum CO_2 emissions from 2015 to 2016 offset some of the emission reductions from decreased coal use in the electric power sector and decreased demand for heating fuel in the residential and commercial sectors. Although emissions from the transportation sector have increased, emissions from all other sectors and U.S. Territories have decreased in recent years, contributing to a 1.6 percent decrease in total CO_2 emissions from fossil fuel combustion from 2015 to 2016 and a 7.3 percent reduction since 2010.

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 fuel consumption and appropriate fuel properties described below. (Any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report.)

- *Electric Power.* 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. (Non-utility power producers are included in this sector as long as they meet the electric power sector definition.)
- *Industry.* 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 industrial sector consist 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.)
- *Transportation.* 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.
- *Residential.* EIA's fuel consumption data for the residential sector consist of living quarters for private households.
- *Commercial.* 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.)

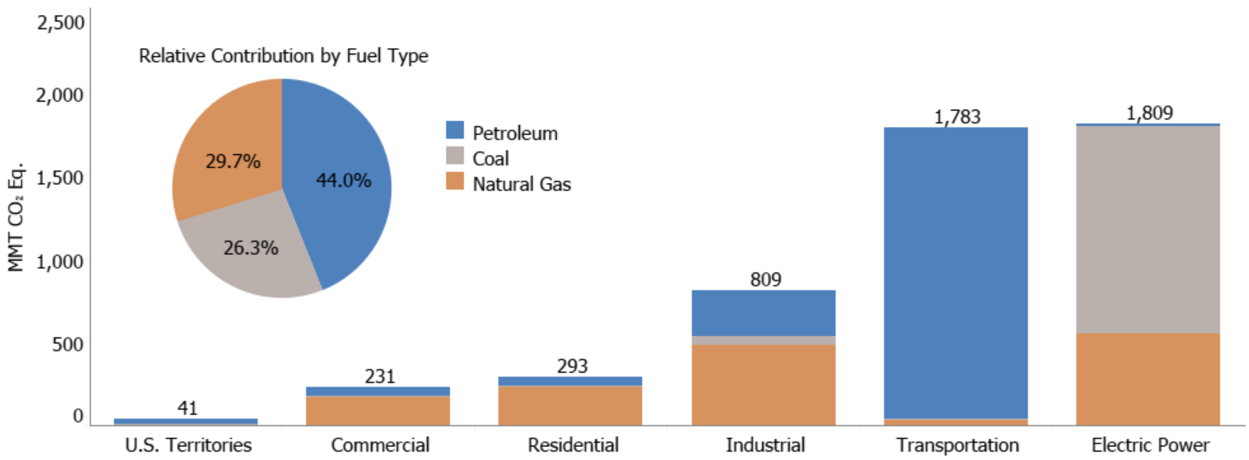
End-Use Sector	1990	2005	2012	2013	2014	2015	2016
Transportation	**1,470.6**	**1,860.5**	**1,665.8**	**1,681.6**	**1,721.2**	**1,739.2**	**1,786.1**
Combustion	1,467.6	1,855.8	1,661.9	1,677.6	1,717.1	1,735.5	1,782.6
Electricity	3.0	4.7	3.9	4.0	4.1	3.7	3.5
Industrial	**1,545.6**	**1,592.3**	**1,405.7**	**1,438.0**	**1,418.1**	**1,359.0**	**1,326.7**
Combustion	858.8	855.7	812.9	843.3	824.9	809.5	809.1
Electricity	686.7	736.6	592.8	594.7	593.2	549.6	517.7
Residential	**931.4**	**1,214.1**	**1,007.8**	**1,064.6**	**1,080.0**	**1,001.1**	**946.7**
Combustion	338.3	357.8	282.5	329.7	345.3	316.8	292.5
Electricity	593.0	856.3	725.3	734.9	734.7	684.3	654.2
Commercial	**765.2**	**1,030.3**	**901.6**	**930.2**	**939.6**	**908.6**	**865.2**
Combustion	227.2	227.0	201.3	225.7	233.6	245.4	231.3
Electricity	538.0	803.3	700.3	704.5	706.0	663.1	633.9

U.S. Territories[a]	**27.6**	**49.7**	**43.5**	**42.5**	**41.4**	**41.4**	**41.4**
Total	**4,740.3**	**5,746.9**	**5,024.4**	**5,156.9**	**5,200.3**	**5,049.3**	**4,966.0**
Electric Power	**1,820.8**	**2,400.9**	**2,022.2**	**2,038.1**	**2,038.0**	**1,900.7**	**1,809.3**

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

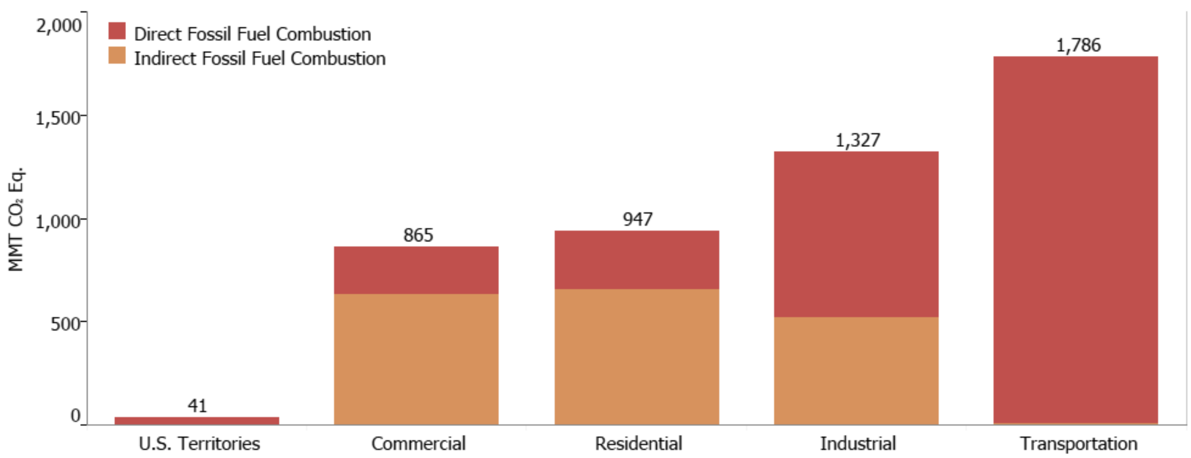
Notes: Combustion-related emissions from electric power are allocated based on aggregate national electricity use by each end-use sector. Totals may not sum due to independent rounding.

Figure 2-7: 2016 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO_2 Eq.)



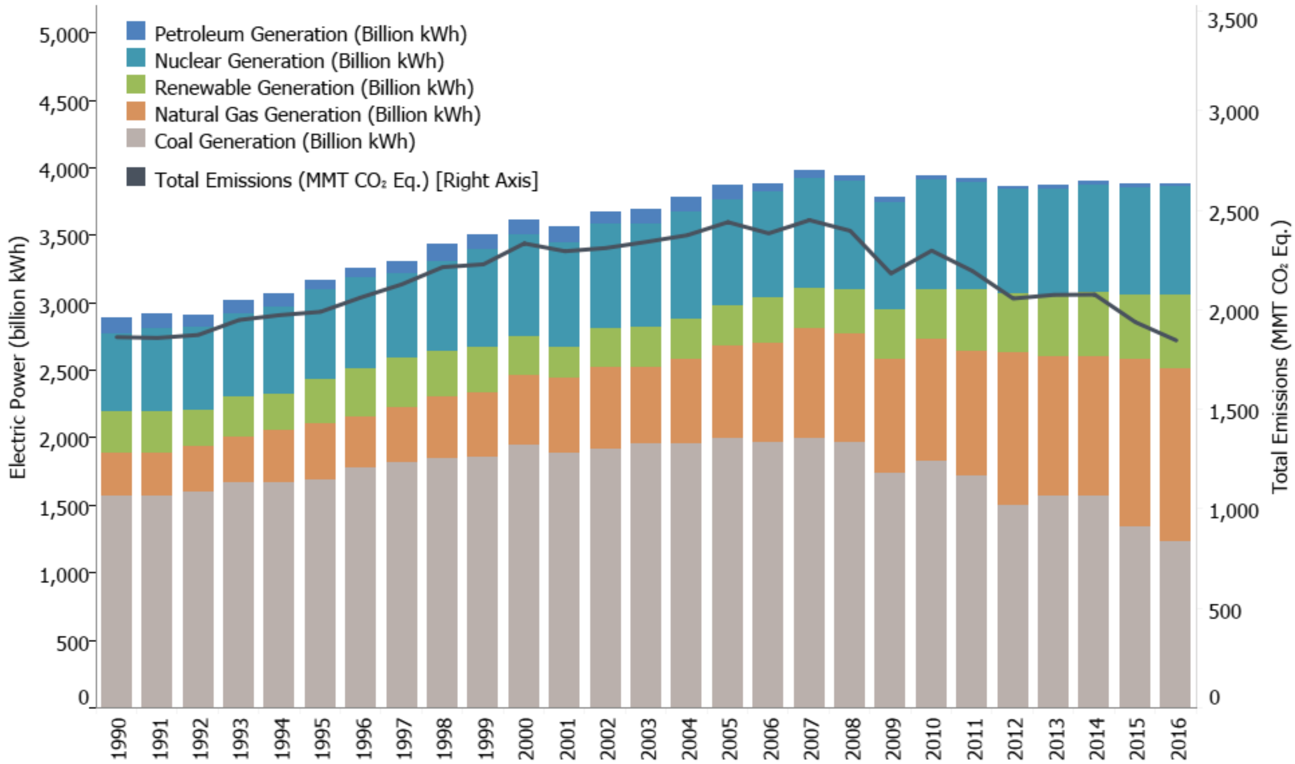
Note on Figure 2-7: Fossil Fuel Combustion for electric power also includes emissions of less than 0.5 MMT CO_2 Eq. from geothermal-based generation.

Figure 2-8: 2016 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. Electric power is the largest emitter of CO_2, and electricity generators used 33 percent of U.S. energy from fossil fuels and emitted 36 percent of the CO_2 from fossil fuel combustion in 2016. Changes in electricity demand and the carbon intensity of fuels used for electric power have a significant impact on CO_2 emissions. Total greenhouse gas emissions from the electric power sector have decreased by approximately 0.1 percent since 1990, and the carbon intensity of the electric power sector, in terms of CO_2 Eq. per QBtu input has significantly decreased by 12 percent during that same timeframe. This decoupling of electric power and the resulting emissions is shown below in Figure 2-9.

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



Electric power emissions can also be allocated to the end-use sectors that are using that electricity, as presented in Table 2-5. The transportation end-use sector accounted for 1,786.1 MMT CO_2 Eq. in 2016 or approximately 36 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 19 and 17 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 use for lighting, heating, air conditioning, and operating appliances contributing 69 and 73 percent of emissions from the residential and commercial end-use sectors, respectively.

Other Significant Trends in Energy

Other significant trends in emissions from energy source categories over the twenty-seven-year period from 1990 through 2016 included the following:

- Methane emissions from natural gas systems and petroleum systems (combined here) decreased from 235.0 MMT CO_2 Eq. in 1990 to 202.1 MMT CO_2 Eq. in 2016 (32.8 MMT CO_2 Eq. or 14.0 percent decrease from 1990 to 2016). Natural gas systems CH_4 emissions decreased by 31.6 MMT CO_2 Eq. (16.2 percent) since 1990, largely due to a decrease in emissions from distribution, transmission and storage, processing, and exploration. 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. The decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and leaks). Petroleum systems CH_4 emissions decreased by 1.2 MMT CO_2 Eq. (or 3.0 percent) since 1990. This decrease is due primarily to decreases in tank emissions and associated gas venting. Carbon dioxide emissions from natural gas and petroleum systems increased by 29 percent from 1990 to 2016, due to increases in flaring emissions.
- Carbon dioxide emissions from non-energy uses of fossil fuels decreased by 7.3 MMT CO_2 Eq. (6.1 percent) from 1990 through 2016. Emissions from non-energy uses of fossil fuels were 112.2 MMT CO_2

Eq. in 2016, which constituted 2.1 percent of total national CO_2 emissions, approximately the same proportion as in 1990.

- Nitrous oxide emissions from stationary combustion increased by 7.5 MMT CO_2 Eq. (67.5 percent) from 1990 through 2016. 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 23.3 MMT CO_2 Eq. (55.9 percent) from 1990 through 2016, 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 2016) increased by 2.7 MMT CO_2 Eq. (34.3 percent) from 1990 through 2016, as the volume of scrap tires and other fossil C-containing materials in waste increased.

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.

In many cases, greenhouse gas emissions are produced as the byproducts 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, N_2O, and fluorinated gases (e.g., HFC-23). These processes are shown in Figure 2-10. Industrial manufacturing processes and use by end-consumers 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 semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. In addition, N_2O is used in and emitted by semiconductor manufacturing and anesthetic and aerosol applications. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-10: 2016 Industrial Processes and Product Use Chapter Greenhouse Gas Sources ($MMT\ CO_2$ Eq.)

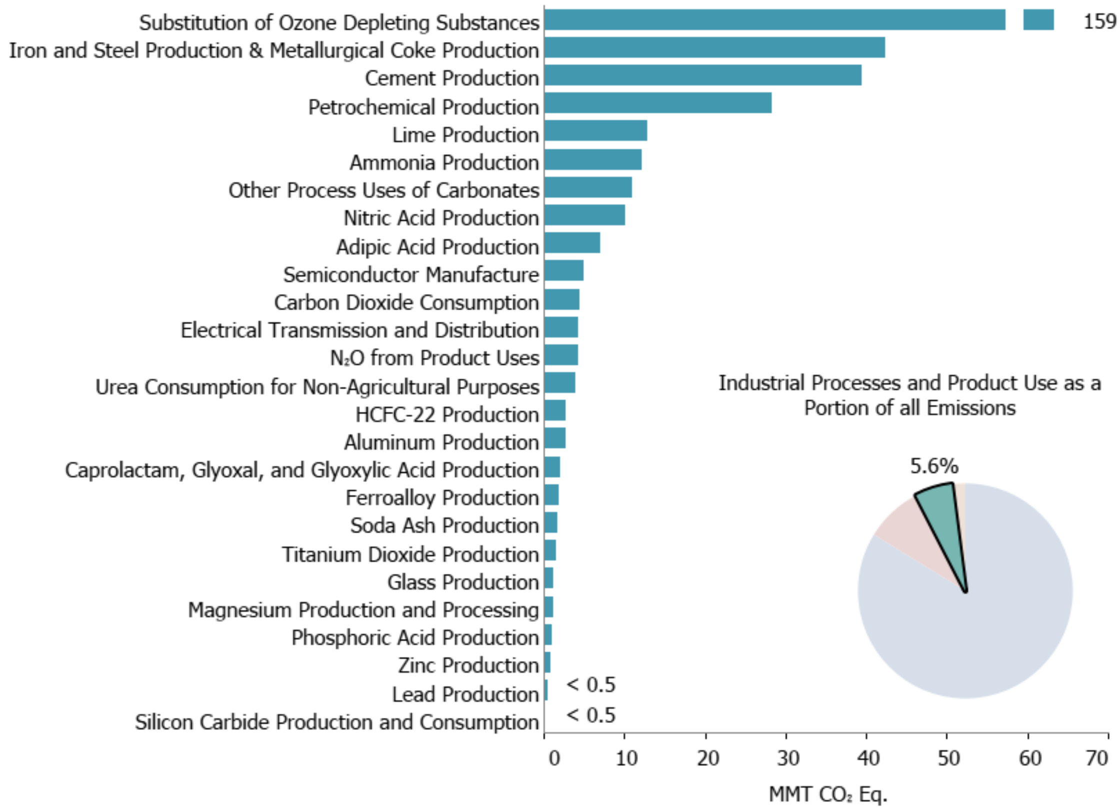


Table 2-6: Emissions from Industrial Processes and Product Use ($MMT\ CO_2$ Eq.)

Gas/Source	1990	2005	2012	2013	2014	2015	2016
CO_2	**208.8**	**191.6**	**171.1**	**173.1**	**179.2**	**172.9**	**164.7**
Iron and Steel Production & Metallurgical Coke Production	101.6	68.2	55.6	53.5	58.4	47.8	42.3
Iron and Steel Production	*99.1*	*66.2*	*55.1*	*51.6*	*56.3*	*45.0*	*41.0*
Metallurgical Coke Production	*2.5*	*2.1*	*0.5*	*1.8*	*2.0*	*2.8*	*1.3*
Cement Production	33.5	46.2	35.3	36.4	39.4	39.9	39.4
Petrochemical Production	21.2	26.8	26.5	26.4	26.5	28.1	28.1
Lime Production	11.7	14.6	13.8	14.0	14.2	13.3	12.9
Ammonia Production	13.0	9.2	9.4	10.0	9.6	10.9	12.2
Other Process Uses of Carbonates	6.3	7.6	9.1	11.5	13.0	12.3	11.0
Carbon Dioxide Consumption	1.5	1.4	4.0	4.2	4.5	4.5	4.5
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.4	4.1	1.5	4.2	4.0
Ferroalloy Production	2.2	1.4	1.9	1.8	1.9	2.0	1.8
Soda Ash Production	1.4	1.7	1.7	1.7	1.7	1.7	1.7
Titanium Dioxide Production	1.2	1.8	1.5	1.7	1.7	1.6	1.6
Aluminum Production	6.8	4.1	3.4	3.3	2.8	2.8	1.3
Glass Production	1.5	1.9	1.2	1.3	1.3	1.3	1.2
Phosphoric Acid Production	1.5	1.3	1.1	1.1	1.0	1.0	1.0
Zinc Production	0.6	1.0	1.5	1.4	1.0	0.9	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**	**0.2**	**0.2**	**0.3**
Petrochemical Production	0.2	0.1	0.1	0.1	0.1	0.2	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	**33.3**	**24.9**	**22.4**	**21.0**	**22.8**	**22.3**	**23.6**
Nitric Acid Production	12.1	11.3	10.5	10.7	10.9	11.6	10.2
Adipic Acid Production	15.2	7.1	5.5	3.9	5.4	4.3	7.0
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Caprolactam, Glyoxal, and Glyoxylic Acid	1.7	2.1	2.0	2.0	2.0	2.0	2.0
Semiconductor Manufacturing	+	0.1	0.2	0.2	0.2	0.2	0.2
HFCs	**46.6**	**123.0**	**150.5**	**151.1**	**156.7**	**160.8**	**162.3**
Substitution of Ozone Depleting Substances[a]	0.3	102.7	144.8	146.8	151.3	156.1	159.1
HCFC-22 Production	46.1	20.0	5.5	4.1	5.0	4.3	2.8
Semiconductor Manufacturing	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	0.1	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**5.9**	**5.8**	**5.6**	**5.1**	**4.3**
Semiconductor Manufacturing	2.8	3.3	3.0	2.8	3.1	3.1	3.0
Aluminum Production	21.5	3.4	2.9	3.0	2.5	2.0	1.4
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF_6	**28.8**	**11.8**	**6.7**	**6.3**	**6.4**	**5.9**	**6.2**
Electrical Transmission and Distribution	23.1	8.3	4.7	4.5	4.7	4.3	4.3
Magnesium Production and Processing	5.2	2.7	1.6	1.5	1.0	0.9	1.0
Semiconductor Manufacturing	0.5	0.7	0.3	0.4	0.7	0.7	0.8
NF_3	**+**	**0.5**	**0.6**	**0.6**	**0.5**	**0.6**	**0.6**
Semiconductor Manufacturing	+	0.5	0.6	0.6	0.5	0.6	0.6
Total	**342.0**	**358.6**	**357.4**	**357.9**	**371.4**	**367.8**	**362.1**

+ 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 5.9 percent from 1990 to 2016. Significant trends in emissions from IPPU source categories over the twenty-seven-year period from 1990 through 2016 included the following:

- Hydrofluorocarbon and perfluorocarbon emissions from ODS substitutes have been increasing from small amounts in 1990 to 159.1 MMT CO_2 Eq. in 2016. 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 11.5 percent to 42.3 MMT CO_2 Eq. from 2015 to 2016, and have declined overall by 59.3 MMT CO_2 Eq. (58.4 percent) from 1990 through 2016, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.

- Carbon dioxide emissions from ammonia production (12.2 MMT CO_2 Eq. in 2016) decreased by 0.9 MMT CO_2 Eq. (6.5 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.

- Nitrous oxide emissions from adipic acid production were 7.0 MMT CO_2 Eq. in 2016, 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 53.9 percent since 1990 and by 58.5 percent since a peak in 1995.

- PFC emissions from aluminum production decreased by 93.7 percent (20.1 MMT CO_2 Eq.) from 1990 to 2016, 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. Methane, N_2O, and CO_2 were the primary greenhouse gases emitted by agricultural activities.

In 2016, agricultural activities were responsible for emissions of 562.6 MMT CO_2 Eq., or 8.6 percent of total U.S. greenhouse gas emissions. Methane emissions from enteric fermentation and manure management represented approximately 25.9 percent and 10.3 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2016. 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 2016, accounting for 76.7 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: 2016 Agriculture Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

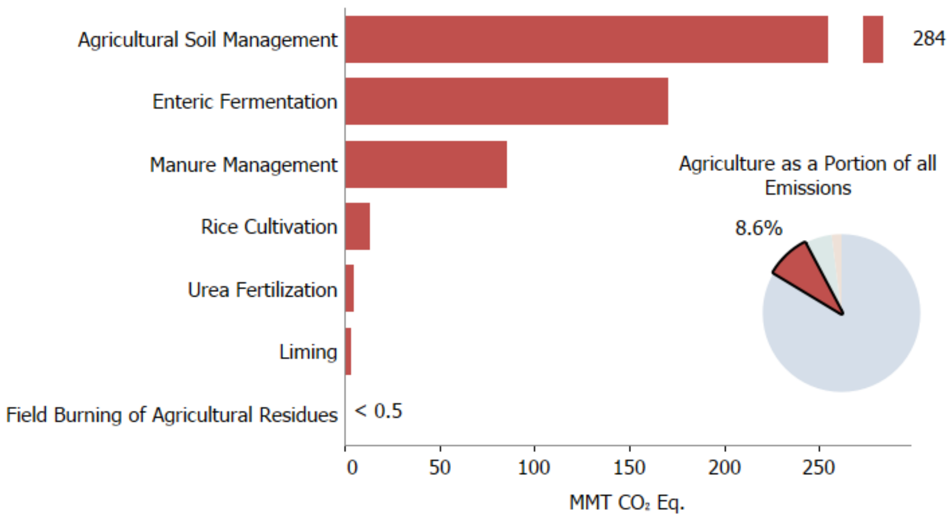


Table 2-7: Emissions from Agriculture (MMT CO_2 Eq.)

Gas/Source	1990		2005		2012	2013	2014	2015	2016
CO_2	**7.1**		**7.9**		**10.3**	**8.4**	**8.1**	**8.7**	**9.0**
Urea Fertilization	2.4		3.5		4.3	4.4	4.5	4.9	5.1
Liming	4.7		4.3		6.0	3.9	3.6	3.8	3.9
CH_4	**217.6**		**242.1**		**244.0**	**240.6**	**240.1**	**245.4**	**251.8**
Enteric Fermentation	164.2		168.9		166.7	165.5	164.2	166.5	170.1
Manure Management	37.2		56.3		65.6	63.3	62.9	66.3	67.7
Rice Cultivation	16.0		16.7		11.3	11.5	12.7	12.3	13.7
Field Burning of Agricultural Residues	0.2		0.2		0.3	0.3	0.3	0.3	0.3
N_2O	**264.5**		**270.1**		**265.5**	**294.2**	**291.6**	**312.8**	**301.8**
Agricultural Soil Management	250.5		253.5		247.9	276.6	274.0	295.0	283.6
Manure Management	14.0		16.5		17.5	17.5	17.5	17.7	18.1
Field Burning of Agricultural Residues	0.1		0.1		0.1	0.1	0.1	0.1	0.1
Total	**489.2**		**520.0**		**519.8**	**543.1**	**539.8**	**566.9**	**562.6**

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 is the largest anthropogenic source of N_2O emissions in the United States, accounting for approximately 76.7 percent of N_2O emissions in 2016. Estimated emissions from this source in 2016 were 283.6 MMT CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2016, although overall emissions were 13.2 percent higher in 2016 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 2016, enteric fermentation CH_4 emissions were 170.1 MMT CO_2 Eq. (25.9 percent of total CH_4 emissions), which represents an increase of 6.0 MMT CO_2 Eq. (3.6 percent) since 1990. This increase in emissions from 1990 to 2016 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 2014 as beef cattle populations again decreased. Emissions increased from 2014 to 2016, consistent with an increase in beef cattle population over those same years.
- Liming and urea fertilization are the only source of CO_2 emissions reported in the Agriculture sector. Estimated emissions from these sources were 3.9 and 5.1 MMT CO_2 Eq., respectively. Liming and urea fertilization emissions increased by 2.3 percent and 4.3 percent, respectively, relative to 2015, and decreased by 17.2 percent and increased by 110.9 percent, respectively since 1990.
- Overall, emissions from manure management increased 67.8 percent between 1990 and 2016. This encompassed an increase of 82.2 percent for CH_4, from 37.2 MMT CO_2 Eq. in 1990 to 67.7 MMT CO_2 Eq. in 2016; and an increase of 29.6 percent for N_2O, from 14.0 MMT CO_2 Eq. in 1990 to 18.1 MMT CO_2 Eq. in 2016. The majority of the increase observed in CH_4 resulted from swine and dairy cattle manure, where emissions increased 63 and 140 percent, respectively, from 1990 to 2016. From 2015 to 2016, there was a 2.2 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 2016 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 754.9 MMT CO_2 Eq. (Table 2-8).[2] This represents an offset of approximately 11.6 percent of total (i.e., gross) greenhouse gas emissions in 2016. Emissions of CH_4 and N_2O from LULUCF activities in 2016 were 38.1 MMT CO_2 Eq. and represent 0.6 percent of total greenhouse gas emissions.[3] Between 1990 and 2016, total C sequestration in the LULUCF sector decreased by 9.1 percent, primarily due to a decrease in the rate of net C accumulation in forests and *Cropland Remaining Cropland*, as well as an increase in CO_2 emissions from *Land Converted to Settlements*.

Forest fires were the largest source of CH_4 emissions from LULUCF in 2016, totaling 18.5 MMT CO_2 Eq. (740 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 0.3 MMT CO_2 Eq. (11 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 2016, totaling 12.2 MMT CO_2 Eq. (41 kt of N_2O). Nitrous oxide emissions from fertilizer application to settlement soils in 2016 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). Additionally, the application of synthetic fertilizers to forest soils in 2016 resulted in N_2O emissions of 0.5 MMT CO_2 Eq. (2 kt of N_2O). Grassland fires resulted in N_2O emissions of 0.3 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). *Peatlands Remaining Peatlands* resulted in N_2O emissions of less than 0.05 MMT CO_2 Eq.

Carbon dioxide removals from C stock changes are presented in Figure 2-12 and Table 2-8 along with CH_4 and N_2O emissions for LULUCF source categories.

[2] 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.*

[3] 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.

Figure 2-12: 2016 LULUCF Chapter Greenhouse Gas Sources and Sinks (MMT CO_2 Eq.)

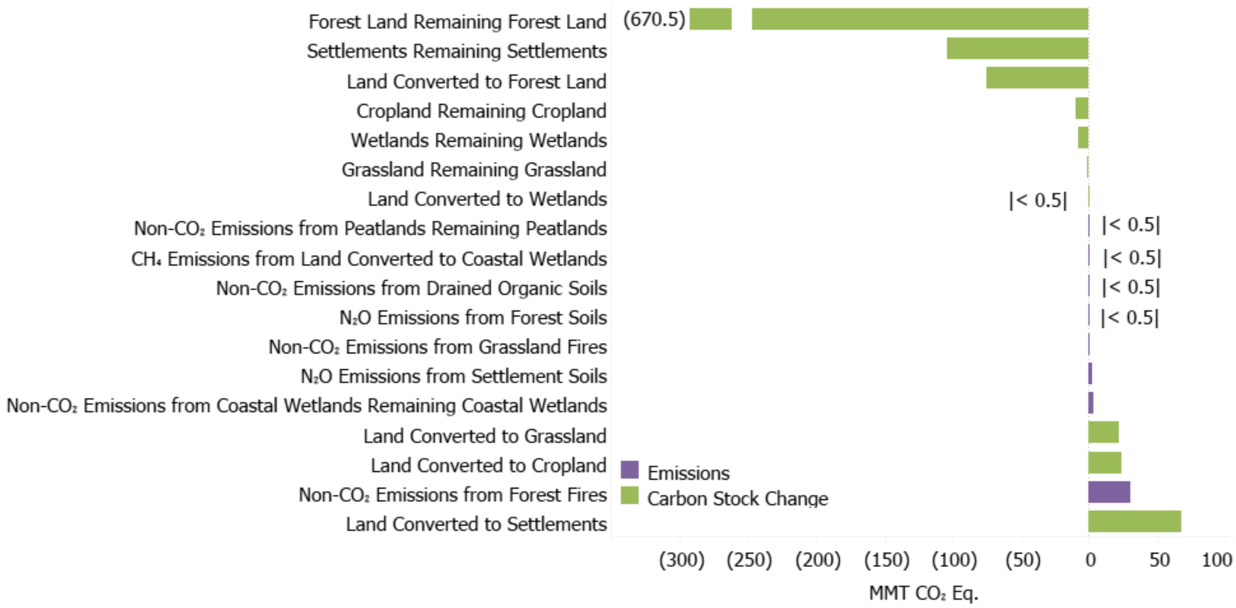


Table 2-8: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 Eq.)

Gas/Land-Use Category	1990	2005	2012	2013	2014	2015	2016
Carbon Stock Change[a]	**(830.2)**	**(754.2)**	**(779.5)**	**(755.0)**	**(760.0)**	**(733.4)**	**(754.9)**
Forest Land Remaining Forest Land	(697.7)	(664.6)	(666.9)	(670.9)	(669.3)	(666.2)	(670.5)
Land Converted to Forest Land	(92.0)	(81.6)	(74.9)	(74.9)	(75.0)	(75.0)	(75.0)
Cropland Remaining Cropland	(40.9)	(26.5)	(21.4)	(11.4)	(12.0)	(6.3)	(9.9)
Land Converted to Cropland	43.3	25.9	22.7	23.3	23.2	23.2	23.8
Grassland Remaining Grassland	(4.2)	5.5	(20.8)	(3.7)	(7.5)	9.6	(1.6)
Land Converted to Grassland	17.9	19.2	20.4	21.9	21.5	23.3	22.0
Wetlands Remaining Wetlands	(7.6)	(8.9)	(7.7)	(7.8)	(7.8)	(7.8)	(7.9)
Land Converted to Wetlands	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Settlements Remaining Settlements	(86.2)	(91.4)	(99.2)	(99.8)	(101.2)	(102.2)	(103.7)
Land Converted to Settlements	37.2	68.4	68.3	68.3	68.2	68.1	68.0
CH_4	**6.7**	**13.3**	**15.0**	**10.9**	**11.2**	**22.4**	**22.4**
Forest Land Remaining Forest Land: Forest Fires	3.2	9.4	10.8	7.2	7.2	18.5	18.5
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands	3.4	3.5	3.5	3.6	3.6	3.6	3.6
Grassland Remaining Grassland: Grassland Fires	0.1	0.3	0.6	0.2	0.4	0.3	0.3
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**	**11.1**	**8.3**	**8.4**	**15.8**	**15.7**
Forest Land Remaining Forest Land: Forest Fires	2.1	6.2	7.1	4.8	4.7	12.2	12.2
Settlements Remaining Settlements: Settlement Soils[b]	1.4	2.5	2.7	2.6	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:	0.1	0.3	0.6	0.2	0.4	0.3	0.3

Grassland Fires							
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**	**26.1**	**19.2**	**19.6**	**38.2**	**38.1**
LULUCF Carbon Stock Change[a]	**(830.2)**	**(754.2)**	**(779.5)**	**(755.0)**	**(760.0)**	**(733.4)**	**(754.9)**
LULUCF Sector Net Total[e]	**(819.6)**	**(731.1)**	**(753.5)**	**(735.8)**	**(740.4)**	**(695.2)**	**(716.8)**

+ 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 2016 in emissions from LULUCF categories include:

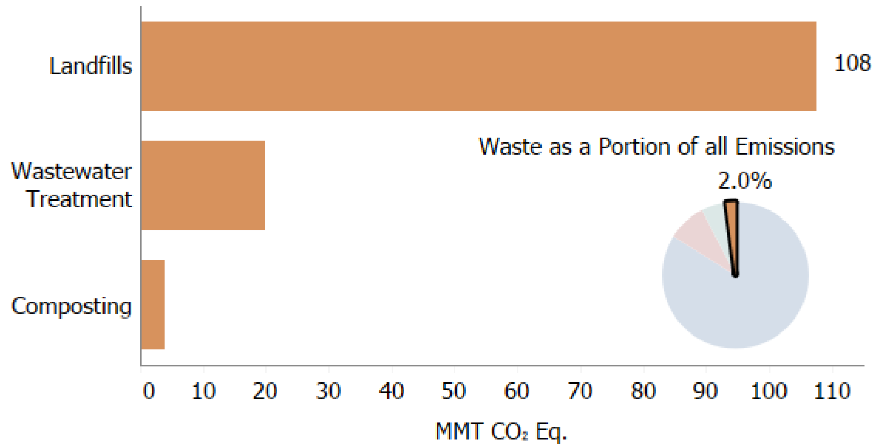
- Annual C sequestration by forest land (i.e., annual C stock accumulation in the five C pools and harvested wood products for *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*) has decreased by approximately 5.6 percent since 1990. This is primarily due to decreased C stock gains 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 20.2 percent over the period from 1990 to 2016. 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 23.3 percent from 1990 to 2016 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 82.6 percent from 1990 to 2016 due to losses in aboveground biomass C stocks from *Forest Land Converted to Settlements* and mineral soils C stocks from *Grassland Converted to Settlements*.
- Nitrous oxide emissions from fertilizer application to settlement soils in 2016 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). This represents an increase of 74.6 percent since 1990. Additionally, the application of synthetic fertilizers to forest soils in 2016 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.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-13). In 2016, landfills were the third-largest source of U.S. anthropogenic CH_4 emissions, accounting for 16.4 percent of total

U.S. CH_4 emissions.[4] Additionally, wastewater treatment accounts for 15.1 percent of Waste emissions, 2.3 percent of U.S. CH_4 emissions, and 1.3 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2016, and resulted in emissions of 4.0 MMT CO_2 Eq. in 2016. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-9.

Figure 2-13: 2016 Waste Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)



Overall, in 2016, waste activities generated emissions of 131.5 MMT CO_2 Eq., or 2.0 percent of total U.S. greenhouse gas emissions.

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

Gas/Source	1990	2005	2012	2013	2014	2015	2016
CH_4	**195.6**	**150.4**	**134.0**	**130.2**	**129.8**	**128.9**	**124.6**
Landfills	179.6	132.7	117.0	113.3	112.7	111.7	107.7
Wastewater Treatment	15.7	15.8	15.1	14.9	15.0	15.1	14.8
Composting	0.4	1.9	1.9	2.0	2.1	2.1	2.1
N_2O	**3.7**	**6.1**	**6.4**	**6.5**	**6.7**	**6.7**	**6.8**
Wastewater Treatment	3.4	4.4	4.6	4.7	4.8	4.8	5.0
Composting	0.3	1.7	1.7	1.8	1.9	1.9	1.9
Total	**199.3**	**156.4**	**140.4**	**136.7**	**136.5**	**135.6**	**131.5**

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 2016, net CH_4 emissions from landfills decreased by 71.9 MMT CO_2 Eq. (40.0 percent), with small increases occurring in interim years. This downward trend in emissions coincided with increased landfill gas collection and control systems, and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in municipal solid waste (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 2016, which represents slightly less 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.

[4] 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.

- From 1990 to 2016, CH_4 and N_2O emissions from wastewater treatment decreased by 0.9 MMT CO_2 Eq. (5.5 percent) and increased by 1.6 MMT CO_2 Eq. (46.5 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; IPPU; Agriculture; LULUCF; and Waste. While it is important to use this characterization for consistency with United Nations Framework Convention on Climate Change (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, electric power, and agriculture, as well as U.S. Territories.

Using this categorization, transportation activities, in aggregate, accounted for the largest portion (28.5 percent) of total U.S. greenhouse gas emissions in 2016. Emissions from electric power, in aggregate, accounted for the second largest portion (28.4 percent). Emissions from industry accounted for about 22 percent of total U.S. greenhouse gas emissions in 2016. 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 5 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 6 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 2-14 shows the trend in emissions by sector from 1990 to 2016.

Figure 2-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

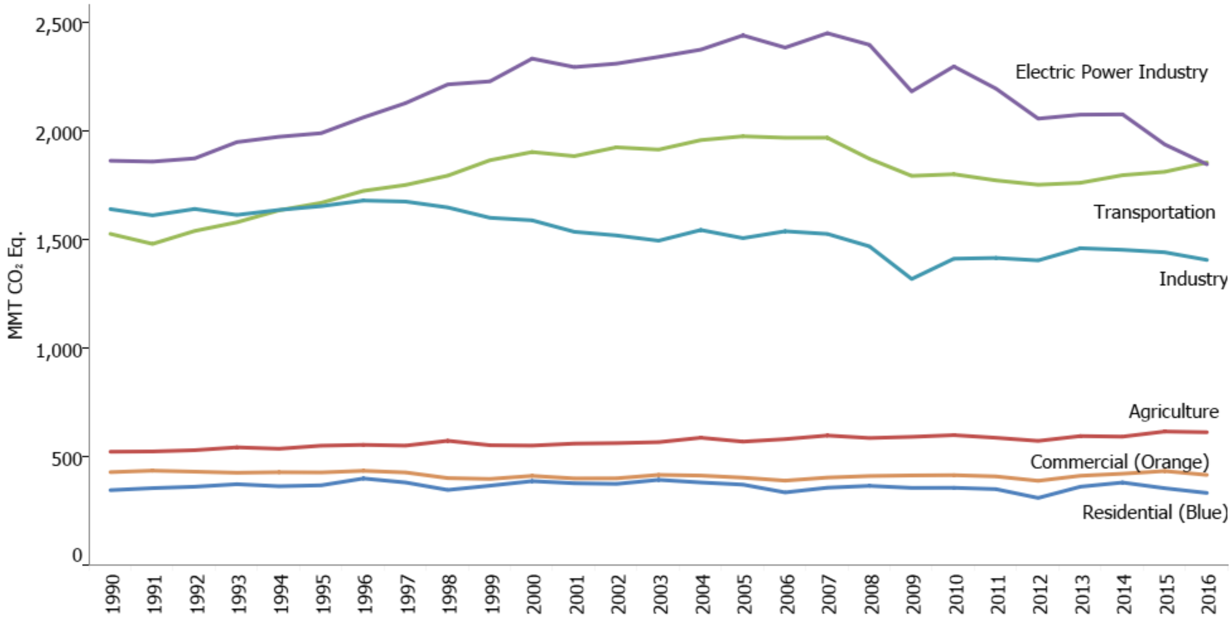


Table 2-10: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq. and Percent of Total in 2016)

Sector/Source	1990	2005	2012	2013	2014	2015	2016[a]	Percent[a]
Transportation	**1,525.5**	**1,974.9**	**1,751.9**	**1,760.6**	**1,795.9**	**1,811.4**	**1,854.0**	**28.5%**
CO_2 from Fossil Fuel Combustion	1,467.6	1,855.8	1,661.9	1,677.6	1,717.1	1,735.5	1,782.6	27.4%
Substitution of Ozone Depleting Substances	+	69.5	58.1	52.7	50.0	47.7	44.8	0.7%
Mobile Combustion	46.1	39.5	23.6	21.6	19.6	18.2	17.2	0.3%
Non-Energy Use of Fuels	11.8	10.2	8.3	8.8	9.1	10.0	9.5	0.1%
Electric Power Industry	**1,862.4**	**2,439.9**	**2,056.3**	**2,074.7**	**2,076.1**	**1,937.5**	**1,846.1**	**28.4%**
CO_2 from Fossil Fuel Combustion	1,820.8	2,400.9	2,022.2	2,038.1	2,038.0	1,900.7	1,809.3	27.8%
Stationary Combustion	6.9	14.0	14.2	15.6	16.0	15.4	16.0	0.2%
Incineration of Waste	8.4	12.9	10.7	10.7	10.9	11.0	11.0	0.2%
Other Process Uses of Carbonates	3.1	3.8	4.6	5.8	6.5	6.2	5.5	0.1%
Electrical Transmission and Distribution	23.1	8.3	4.7	4.5	4.7	4.3	4.3	0.1%
Industry	**1,639.5**	**1,505.8**	**1,403.4**	**1,459.5**	**1,452.1**	**1,440.7**	**1,405.5**	**21.6%**
CO_2 from Fossil Fuel Combustion	827.2	808.3	761.9	793.2	774.2	762.0	760.7	11.7%
Natural Gas Systems	225.0	191.6	182.9	188.6	189.6	191.2	189.0	2.9%
Non-Energy Use of Fuels	102.1	120.6	94.9	109.3	104.6	110.6	97.6	1.5%
Petroleum Systems	47.5	43.8	52.0	59.2	64.9	66.8	61.4	0.9%
Coal Mining	96.5	64.1	66.5	64.6	64.6	61.2	53.8	0.8%
Iron and Steel Production	101.7	68.2	55.6	53.5	58.4	47.8	42.3	0.6%
Cement Production	33.5	46.2	35.3	36.4	39.4	39.9	39.4	0.6%
Petrochemical Production	21.4	26.9	26.6	26.5	26.6	28.2	28.4	0.4%
Substitution of Ozone Depleting Substances	+	7.9	19.7	21.4	23.2	25.7	27.8	0.4%
Lime Production	11.7	14.6	13.8	14.0	14.2	13.3	12.9	0.2%
Ammonia Production	13.0	9.2	9.4	10.0	9.6	10.9	12.2	0.2%
Nitric Acid Production	12.1	11.3	10.5	10.7	10.9	11.6	10.2	0.2%
Abandoned Oil and Gas Wells	6.5	6.9	7.0	7.0	7.1	7.2	7.1	0.1%

Adipic Acid Production	15.2	7.1	5.5	3.9	5.4	4.3	7.0	0.1%
Abandoned Underground Coal Mines	7.2	6.6	6.2	6.2	6.3	6.4	6.7	0.1%
Other Process Uses of Carbonates	3.1	3.8	4.6	5.8	6.5	6.2	5.5	0.1%
Semiconductor Manufacture	3.6	4.7	4.4	4.0	4.9	5.0	5.0	0.1%
Carbon Dioxide Consumption	1.5	1.4	4.0	4.2	4.5	4.5	4.5	0.1%
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.1%
Mobile Combustion	7.2	7.6	4.8	4.7	4.4	4.2	4.1	0.1%
Stationary Combustion	4.9	4.7	4.2	4.3	4.2	4.1	4.0	0.1%
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.4	4.1	1.5	4.2	4.0	0.1%
HCFC-22 Production	46.1	20.0	5.5	4.1	5.0	4.3	2.8	+%
Aluminum Production	28.3	7.6	6.4	6.2	5.4	4.8	2.7	+%
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	2.0	2.0	2.0	2.0	2.0	+%
Ferroalloy Production	2.2	1.4	1.9	1.8	1.9	2.0	1.8	+%
Soda Ash Production	1.4	1.7	1.7	1.7	1.7	1.7	1.7	+%
Titanium Dioxide Production	1.2	1.8	1.5	1.7	1.7	1.6	1.6	+%
Glass Production	1.5	1.9	1.2	1.3	1.3	1.3	1.2	+%
Magnesium Production and Processing	5.2	2.7	1.7	1.5	1.1	1.0	1.1	+%
Phosphoric Acid Production	1.5	1.3	1.1	1.1	1.0	1.0	1.0	+%
Zinc Production	0.6	1.0	1.5	1.4	1.0	0.9	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	**522.0**	**568.5**	**571.8**	**594.1**	**591.5**	**615.1**	**611.8**	**9.4%**
N_2O from Agricultural Soil Management	250.5	253.5	247.9	276.6	274.0	295.0	283.6	4.4%
Enteric Fermentation	164.2	168.9	166.7	165.5	164.2	166.5	170.1	2.6%
Manure Management	51.1	72.9	83.2	80.8	80.4	84.0	85.9	1.3%
CO_2 from Fossil Fuel Combustion	31.6	47.4	51.1	50.0	50.8	47.5	48.4	0.7%
Rice Cultivation	16.0	16.7	11.3	11.5	12.7	12.3	13.7	0.2%
Urea Fertilization	2.4	3.5	4.3	4.4	4.5	4.9	5.1	0.1%
Liming	4.7	4.3	6.0	3.9	3.6	3.8	3.9	0.1%
Mobile Combustion	1.2	1.1	0.9	0.8	0.8	0.7	0.7	+%
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	0.1	0.1	0.1	+%
Commercial	**428.0**	**402.6**	**388.0**	**411.3**	**420.8**	**432.9**	**415.2**	**6.4%**
CO_2 from Fossil Fuel Combustion	227.2	227.0	201.3	225.7	233.6	245.4	231.3	3.6%
Landfills	179.6	132.7	117.0	113.3	112.7	111.7	107.7	1.7%
Substitution of Ozone Depleting Substances	+	17.6	45.1	47.5	49.3	50.3	50.9	0.8%
Wastewater Treatment	15.7	15.8	15.1	14.9	15.0	15.1	14.8	0.2%
Human Sewage	3.4	4.4	4.6	4.7	4.8	4.8	5.0	0.1%
Composting	0.7	3.5	3.7	3.9	4.0	4.0	4.0	0.1%
Stationary Combustion	1.5	1.4	1.2	1.4	1.4	1.6	1.5	+%
Residential	**344.9**	**370.4**	**309.0**	**360.9**	**380.1**	**353.9**	**332.1**	**5.1%**
CO_2 from Fossil Fuel Combustion	338.3	357.8	282.5	329.7	345.3	316.8	292.5	4.5%
Substitution of Ozone Depleting Substances	0.3	7.7	22.1	25.2	28.8	32.3	35.5	0.5%
Stationary Combustion	6.3	4.9	4.5	5.9	6.1	4.7	4.1	0.1%
U.S. Territories	**33.3**	**58.1**	**48.5**	**48.1**	**46.6**	**46.6**	**46.6**	**0.7%**
CO_2 from Fossil Fuel Combustion	27.6	49.7	43.5	42.5	41.4	41.4	41.4	0.6%
Non-Energy Use of Fuels	5.7	8.1	4.8	5.4	5.1	5.1	5.1	0.1%
Stationary Combustion	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+%
Total Emissions	**6,355.6**	**7,320.3**	**6,528.8**	**6,709.1**	**6,763.1**	**6,638.1**	**6,511.3**	**100.0%**

LULUCF Sector Net Total[b]	**(819.6)**		**(731.1)**		**(753.5)**	**(735.8)**	**(740.4)**	**(695.2)**	**(716.8)**	**(11.0%)**
Net Emissions (Sources and Sinks)	**5,536.0**		**6,589.1**		**5,775.3**	**5,973.3**	**6,022.8**	**5,942.9**	**5,794.5**	**89.0%**

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] Percent of total (gross) emissions excluding emissions from LULUCF for 2016.
[b] 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 electric power distributed into end-use categories (i.e., emissions from electric power are allocated to the economic sectors in which the electricity is used). The generation, transmission, and distribution of electricity, which is the second largest economic sector in the United States, accounted for 28 percent of total U.S. greenhouse gas emissions in 2016. Electric power-related emissions decreased by 1 percent since 1990 and by 4.7 percent from 2015 to 2016, primarily due to decreased CO_2 emissions from fossil fuel combustion due to increased natural gas consumption and decreased coal consumption.

Overall, between 2015 and 2016, the amount of electricity generated (in kWh) increased by less than 0.1 percent. However, total emissions from the electric power sector decreased by 4.7 percent from 2015 to 2016 due to changes in the consumption of coal and natural gas for electric power, which were driven by changes in their relative prices. Coal consumption decreased by 8.1 percent, while natural gas consumption increased by 3.8 percent. The consumption of petroleum for electric power decreased by 11.6 percent in 2016 relative to 2015.

Electricity sales to the residential and commercial end-use sectors each increased by 0.5 percent from 2015 to 2016. The sales trend in the residential sector can largely be attributed to an increase in the number of households in the United States. The sales trend in the commercial sector can largely be attributed to increases in commercial floorspace (EIA 2018a). Electricity sales to the industrial sector from 2015 to 2016 decreased by approximately 1.0 percent.

Table 2-11 provides a detailed summary of emissions from electric power-related activities.

Table 2-11: Electric Power-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Fuel Type or Source	1990		2005		2012	2013	2014	2015	2016
CO_2	**1,831.9**		**2,417.2**		**2,037.1**	**2,054.2**	**2,055.1**	**1,917.5**	**1,825.4**
Fossil Fuel Combustion	1,820.8		2,400.9		2,022.2	2,038.1	2,038.0	1,900.7	1,809.3
Coal	*1,547.6*		*1,983.8*		*1,511.2*	*1,571.3*	*1,569.1*	*1,350.5*	*1,241.4*
Natural Gas	*175.3*		*318.8*		*492.2*	*444.0*	*443.2*	*526.1*	*546.0*
Petroleum	*97.5*		*97.9*		*18.3*	*22.4*	*25.3*	*23.7*	*21.4*
Geothermal	*0.4*		*0.4*		*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0		12.5		10.4	10.4	10.6	10.7	10.7
Other Process Uses of Carbonates	3.1		3.8		4.6	5.8	6.5	6.2	5.5
CH_4	**0.4**		**0.9**		**1.1**	**1.0**	**1.0**	**1.1**	**1.1**
Stationary Sources[a]	0.4		0.9		1.1	1.0	1.0	1.1	1.1
Incineration of Waste	+		+		+	+	+	+	+
N_2O	**6.9**		**13.6**		**13.4**	**14.9**	**15.3**	**14.6**	**15.2**
Stationary Sources[a]	6.5		13.2		13.1	14.6	15.0	14.3	14.9
Incineration of Waste	0.5		0.4		0.3	0.3	0.3	0.3	0.3
SF_6	**23.1**		**8.3**		**4.7**	**4.5**	**4.7**	**4.3**	**4.3**
Electrical Transmission and Distribution	23.1		8.3		4.7	4.5	4.7	4.3	4.3
Total	**1,862.4**		**2,439.9**		**2,056.3**	**2,074.7**	**2,076.1**	**1,937.5**	**1,846.1**

+ 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 electric power 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 (EIA 2018b; 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 electric power and distributed as described; the remainder of Other Process Uses of Carbonates emissions were attributed to the industrial processes economic end-use sector.[5]

When emissions from electricity use are distributed among these sectors, industrial activities account for the largest share of total U.S. greenhouse gas emissions (29.1 percent), followed closely by emissions from transportation (28.5 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 81 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 electric power distributed to them. Figure 2-15 shows the trend in these emissions by sector from 1990 to 2016.

Figure 2-15: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO_2 Eq.)

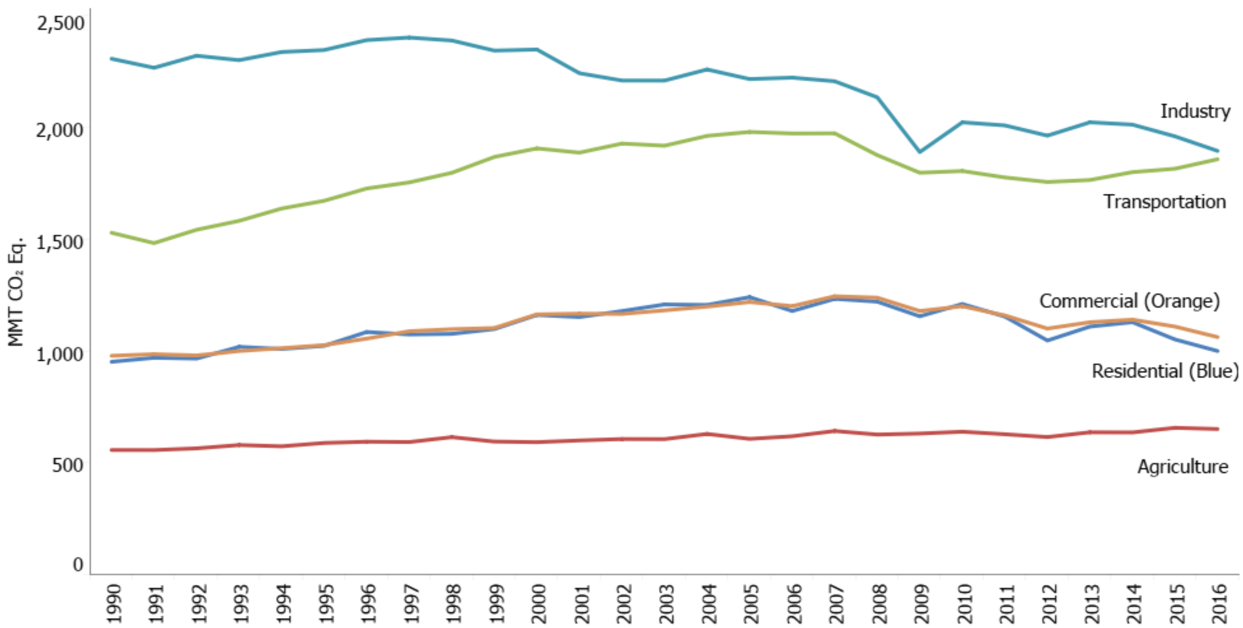


Table 2-12: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (MMT CO_2 Eq.) and Percent of Total in 2016

Sector/Gas	1990	2005	2012	2013	2014	2015	2016	Percent[a]
Industry	**2,307.1**	**2,216.3**	**1,963.1**	**2,022.8**	**2,012.4**	**1,959.9**	**1,894.8**	**29.1%**
Direct Emissions	**1,639.5**	**1,505.8**	**1,403.4**	**1,459.5**	**1,452.1**	**1,440.7**	**1,405.5**	**21.6%**
CO_2	1,172.5	1,150.9	1,066.0	1,117.3	1,103.1	1,093.0	1,065.8	16.4%
CH_4	353.3	286.5	276.4	282.5	284.9	283.0	273.5	4.2%

[5] Emissions were not distributed to U.S. Territories, since the electric power sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

N_2O	37.4	29.6	27.1	25.8	27.6	27.0	28.3	0.4%
HFCs, PFCs, SF_6, and NF_3	76.3	38.8	33.9	33.8	36.5	37.7	37.8	0.6%
Electricity-Related	**667.6**	**710.5**	**559.8**	**563.4**	**560.3**	**519.2**	**489.3**	**7.5%**
CO_2	656.7	703.9	554.6	557.8	554.6	513.9	483.9	7.4%
CH_4	0.2	0.3	0.3	0.3	0.3	0.3	0.3	+%
N_2O	2.5	3.9	3.7	4.1	4.1	3.9	4.0	0.1%
SF_6	8.3	2.4	1.3	1.2	1.3	1.1	1.1	+%
Transportation	**1,528.6**	**1,979.7**	**1,755.8**	**1,764.7**	**1,800.0**	**1,815.1**	**1,857.6**	**28.5%**
Direct Emissions	**1,525.5**	**1,974.9**	**1,751.9**	**1,760.6**	**1,795.9**	**1,811.4**	**1,854.0**	**28.5%**
CO_2	1,479.4	1,865.9	1,670.2	1,686.4	1,726.3	1,745.4	1,792.0	27.5%
CH_4	5.8	3.1	2.0	1.9	1.7	1.7	1.6	+%
N_2O	40.2	36.5	21.6	19.7	17.8	16.5	15.5	0.2%
HFCs[b]	+	69.5	58.1	52.7	50.0	47.7	44.8	0.7%
Electricity-Related	**3.1**	**4.8**	**3.9**	**4.1**	**4.1**	**3.8**	**3.5**	**0.1%**
CO_2	3.1	4.8	3.9	4.0	4.1	3.8	3.5	0.1%
CH_4	+	+	+	+	+	+	+	+%
N_2O	+	+	+	+	+	+	+	+%
SF_6	+	+	+	+	+	+	+	+%
Commercial	**978.3**	**1,218.9**	**1,100.1**	**1,128.4**	**1,140.0**	**1,108.9**	**1,061.9**	**16.3%**
Direct Emissions	**428.0**	**402.6**	**388.0**	**411.3**	**420.8**	**432.9**	**415.2**	**6.4%**
CO_2	227.2	227.0	201.3	225.7	233.6	245.4	231.3	3.6%
CH_4	196.7	151.5	135.0	131.3	130.9	130.1	125.8	1.9%
N_2O	4.1	6.4	6.6	6.8	7.0	7.1	7.2	0.1%
HFCs	+	17.6	45.1	47.5	49.3	50.3	50.9	0.8%
Electricity-Related	**550.3**	**816.3**	**712.1**	**717.1**	**719.2**	**676.0**	**646.8**	**9.9%**
CO_2	541.3	808.7	705.4	710.0	711.9	669.0	639.5	9.8%
CH_4	0.1	0.3	0.4	0.4	0.4	0.4	0.4	+%
N_2O	2.0	4.5	4.6	5.2	5.3	5.1	5.3	0.1%
SF_6	6.8	2.8	1.6	1.5	1.6	1.5	1.5	+%
Residential	**951.5**	**1,240.7**	**1,046.5**	**1,109.0**	**1,128.6**	**1,051.4**	**999.6**	**15.4%**
Direct Emissions	**344.9**	**370.4**	**309.0**	**360.9**	**380.1**	**353.9**	**332.1**	**5.1%**
CO_2	338.3	357.8	282.5	329.7	345.3	316.8	292.5	4.5%
CH_4	5.2	4.1	3.7	5.0	5.1	3.9	3.4	0.1%
N_2O	1.0	0.9	0.7	1.0	1.0	0.8	0.7	+%
HFCs	0.3	7.7	22.1	25.2	28.8	32.3	35.5	0.5%
Electricity-Related	**606.6**	**870.2**	**737.5**	**748.1**	**748.5**	**697.5**	**667.5**	**10.3%**
CO_2	596.6	862.1	730.6	740.7	740.9	690.3	660.1	10.1%
CH_4	0.1	0.3	0.4	0.4	0.4	0.4	0.4	+%
N_2O	2.3	4.8	4.8	5.4	5.5	5.2	5.5	0.1%
SF_6	7.5	3.0	1.7	1.6	1.7	1.5	1.6	+%
Agriculture	**556.9**	**606.6**	**614.8**	**636.1**	**635.5**	**656.1**	**650.7**	**10.0%**
Direct Emissions	**522.0**	**568.5**	**571.8**	**594.1**	**591.5**	**615.1**	**611.8**	**9.4%**
CO_2	38.7	55.2	61.3	58.4	58.9	56.1	57.3	0.9%
CH_4	218.4	242.6	244.3	240.8	240.3	245.5	251.9	3.9%
N_2O	264.9	270.7	266.2	294.9	292.3	313.5	302.5	4.6%
Electricity-Related	**34.8**	**38.0**	**43.0**	**42.0**	**44.0**	**41.0**	**38.9**	**0.6%**
CO_2	34.3	37.7	42.6	41.6	43.6	40.6	38.4	0.6%
CH_4	+	+	+	+	+	+	+	+%
N_2O	0.1	0.2	0.3	0.3	0.3	0.3	0.3	+%
SF_6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	+%
U.S. Territories	**33.3**	**58.1**	**48.5**	**48.1**	**46.6**	**46.6**	**46.6**	**0.7%**
Total Emissions	**6,355.6**	**7,320.3**	**6,528.8**	**6,709.1**	**6,763.1**	**6,638.1**	**6,511.3**	**100.0%**
LULUCF Sector Net Total[c]	**(819.6)**	**(731.1)**	**(753.5)**	**(735.8)**	**(740.4)**	**(695.2)**	**(716.8)**	**(11.0%)**
Net Emissions (Sources and Sinks)	**5,536.0**	**6,589.1**	**5,775.3**	**5,973.3**	**6,022.8**	**5,942.9**	**5,794.5**	**89.0%**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF. Emissions from electric power are allocated based on aggregate electricity use in each end-use sector. Totals may not sum due to independent rounding.

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

[a] Percent of total (gross) emissions excluding emissions from LULUCF for year 2016.

[b] Includes primarily HFC-134a.

[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.

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, byproduct 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. Structural changes within the U.S. economy that led to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) have had a significant effect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 28.5 percent of U.S. greenhouse gas emissions in 2016. The largest sources of transportation greenhouse gases in 2016 were passenger cars (41.6 percent), freight trucks (22.9 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18.0 percent), commercial aircraft (6.5 percent), other aircraft (2.6 percent), ships and boats (2.3 percent), rail (2.2 percent), and pipelines (2.1 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 2016, total transportation emissions increased due, in large part, to increased demand for travel. The number of VMT by light-duty motor vehicles (passenger cars and light-duty trucks) increased 44 percent from 1990 to 2016,[6] 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 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 2014[7] and has since grown at a faster rate (2.6 percent from 2014 to 2015, and 2.5 percent from 2015 to 2016). Average new vehicle fuel economy has increased almost every year since 2005 while the light-duty truck share decreased to about 33 percent in 2009 and has since varied from year to year between 36 percent and 43 percent. Light-duty truck share is about 38 percent of new vehicles in model year 2016 (EPA 2018).

Table 2-13 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals.

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

[6] VMT estimates are based on data from FHWA Highway Statistics Table VM-1 (FHWA 1996 through 2017). 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 2016 time period. In absence of these method changes, light-duty VMT growth between 1990 and 2016 would likely have been even higher.

[7] 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.

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 21 percent from 1990 to 2016.[8] This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 44.8 MMT CO_2 Eq. in 2016, led to an increase in overall emissions from transportation activities of 22 percent.[9]

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

Gas/Vehicle	1990	2005	2012	2013	2014	2015	2016
Passenger Cars	**639.9**	**693.1**	**745.9**	**740.8**	**756.7**	**761.0**	**772.2**
CO_2	612.5	642.6	711.3	710.9	729.6	735.8	749.4
CH_4	3.2	1.3	0.9	0.8	0.7	0.6	0.6
N_2O	24.1	17.6	13.1	11.8	10.5	9.7	8.9
HFCs	0.0	31.7	20.6	17.3	15.9	14.8	13.3
Light-Duty Trucks	**326.9**	**539.7**	**316.2**	**313.2**	**334.2**	**324.8**	**334.2**
CO_2	312.4	490.6	281.3	281.5	304.7	297.4	309.1
CH_4	1.7	0.8	0.3	0.3	0.3	0.2	0.2
N_2O	12.8	15.0	5.3	4.7	4.4	3.8	3.5
HFCs	0.0	33.3	29.3	26.7	24.9	23.3	21.4
Medium- and Heavy-Duty Trucks	**230.3**	**400.3**	**390.5**	**397.4**	**408.7**	**417.1**	**425.9**
CO_2	229.3	395.4	383.6	390.3	401.5	409.7	418.4
CH_4	0.3	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.7	1.2	1.0	0.9	0.9	0.8	0.8
HFCs	0.0	3.6	5.8	6.0	6.3	6.5	6.6
Buses	**8.5**	**12.2**	**18.0**	**18.2**	**19.5**	**19.8**	**19.8**
CO_2	8.4	11.6	17.2	17.5	18.8	19.2	19.1
CH_4	+	0.2	0.3	0.2	0.2	0.2	0.2
N_2O	+	+	+	+	+	+	+
HFCs	0.0	0.3	0.4	0.4	0.4	0.4	0.4
Motorcycles	**1.7**	**1.6**	**4.0**	**3.8**	**3.8**	**3.7**	**3.9**
CO_2	1.7	1.6	3.9	3.7	3.7	3.7	3.8
CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
Commercial Aircraft[a]	**110.9**	**134.0**	**114.3**	**115.4**	**116.3**	**120.1**	**121.5**
CO_2	109.9	132.7	113.3	114.3	115.2	119.0	120.4
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	1.0	1.2	1.0	1.1	1.1	1.1	1.1
Other Aircraft[b]	**78.3**	**59.7**	**32.1**	**34.7**	**35.0**	**40.4**	**47.5**
CO_2	77.5	59.1	31.8	34.4	34.7	40.0	47.0
CH_4	0.1	0.1	+	+	+	+	+
N_2O	0.7	0.5	0.3	0.3	0.3	0.4	0.4
Ships and Boats[c]	**45.3**	**45.8**	**41.9**	**41.5**	**31.0**	**35.7**	**42.8**
CO_2	44.3	44.3	39.3	38.6	28.0	32.3	39.0
CH_4	0.5	0.5	0.4	0.4	0.3	0.3	0.3
N_2O	0.6	0.6	0.5	0.5	0.3	0.4	0.5
HFCs	0.0	0.5	1.7	2.0	2.3	2.6	2.9
Rail	**38.9**	**50.9**	**43.9**	**44.8**	**46.2**	**44.1**	**40.8**
CO_2	38.5	50.3	43.4	44.2	45.6	43.5	40.2
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	0.3	0.3
HFCs	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Other Emissions from Electric Power[d]	0.1	+	+	+	+	+	+

[8] See previous footnote.

[9] See previous footnote.

Pipelines[e]	**36.0**	**32.4**	**40.5**	**46.2**	**39.4**	**38.5**	**39.6**
CO_2	36.0	32.4	40.5	46.2	39.4	38.5	39.6
Lubricants	**11.8**	**10.2**	**8.3**	**8.8**	**9.1**	**10.0**	**9.5**
CO_2	11.8	10.2	8.3	8.8	9.1	10.0	9.5
Total Transportation	**1,528.6**	**1,979.7**	**1,755.8**	**1,764.7**	**1,800.0**	**1,815.1**	**1,857.6**
International Bunker Fuels[f]	*104.5*	*114.2*	*106.8*	*100.7*	*104.4*	*111.9*	*117.7*
Ethanol CO_2[g]	*4.1*	*22.4*	*71.5*	*73.4*	*74.9*	*76.0*	*78.2*
Biodiesel CO_2[g]	*0.0*	*0.9*	*8.5*	*13.5*	*13.3*	*14.1*	*19.6*

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Consists of emissions from jet fuel consumed by domestic operations of commercial aircraft (no bunkers).

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

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

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

[e] 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 Inventory.

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

[g] Ethanol and biodiesel CO_2 estimates are presented for informational purposes only. See Section 3.11 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 use 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 commercial sector have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy use caused by weather conditions, rather than prevailing economic conditions. Decreases in energy-related emissions in the commercial sector in recent years can be largely attributed to an overall reduction in energy use, a reduction in heating degree days, and increases in energy efficiency.

Landfills and wastewater treatment are included in the commercial 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 sector 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, the residential sector is also affected by population growth, migration trends toward warmer areas, and changes in housing and building attributes (e.g., larger sizes and improved insulation). A shift toward energy efficient products and more stringent energy efficiency standards for household equipment has also contributed to recent trends in energy demand in households (EIA 2017a).

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 2016, 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.

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 economic sectors improves communication of the report's findings.

The *Electric Power* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA electric utility fuel-consuming sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA electric power 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" electric power plants. The Electric Power 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 electric power plants).

The *Transportation* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA transportation fuel-consuming sector. (Additional analyses and refinement of the EIA data are further explained in the Energy chapter of this report.) Emissions of CH_4 and N_2O from mobile combustion are also apportioned to the Transportation economic sector based on the EIA transportation fuel-consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned to the Transportation economic sector based on emissions from refrigerated transport and motor vehicle air-conditioning systems. Finally, CO_2 emissions from Non-Energy Uses of Fossil Fuels identified as lubricants for transportation vehicles are included in the Transportation economic sector.

The *Industry* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA industrial fuel-consuming sector, minus the agricultural use of fuel explained below. The CH_4 and N_2O emissions from stationary and mobile combustion are also apportioned to the Industry economic sector based on the EIA industrial fuel-consuming sector, minus emissions apportioned to the Agriculture economic sector. 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 are apportioned to the Industry 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 activities such 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) is 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.

The *Agriculture* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in supplementary sources of agriculture fuel use, because EIA does not include an agriculture fuel-consuming sector. Agriculture equipment is included in the EIA industrial fuel-consuming sector. Agriculture fuel use estimates are obtained from U.S. Department of Agriculture survey data, in combination with separate EIA fuel sales reports (USDA 2018; EIA 2017b). These supplementary data are subtracted from the industrial fuel use reported by EIA to obtain agriculture fuel use. CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion, are then apportioned to the Agriculture economic sector based on agricultural fuel use.

The other emission sources included in the Agriculture 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 Field Burning of Agricultural Residues.

The *Residential* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA residential fuel-consuming 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 to the Residential economic sector based on emissions from residential air-conditioning systems. 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 CO_2 emissions from the combustion of fossil fuels that are included in the EIA commercial fuel-consuming sector. Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to the Commercial economic sector based on the EIA commercial fuel-consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned to the Commercial economic sector based on emissions from commercial refrigeration/air-conditioning systems. Public works sources including direct CH_4 from Landfills, CH_4 and N_2O from Wastewater Treatment, and Composting are also included in the Commercial 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 use, 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 use, because the electric power industry—utilities and non-utilities combined—was the second largest source of U.S. greenhouse gas emissions in 2016; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

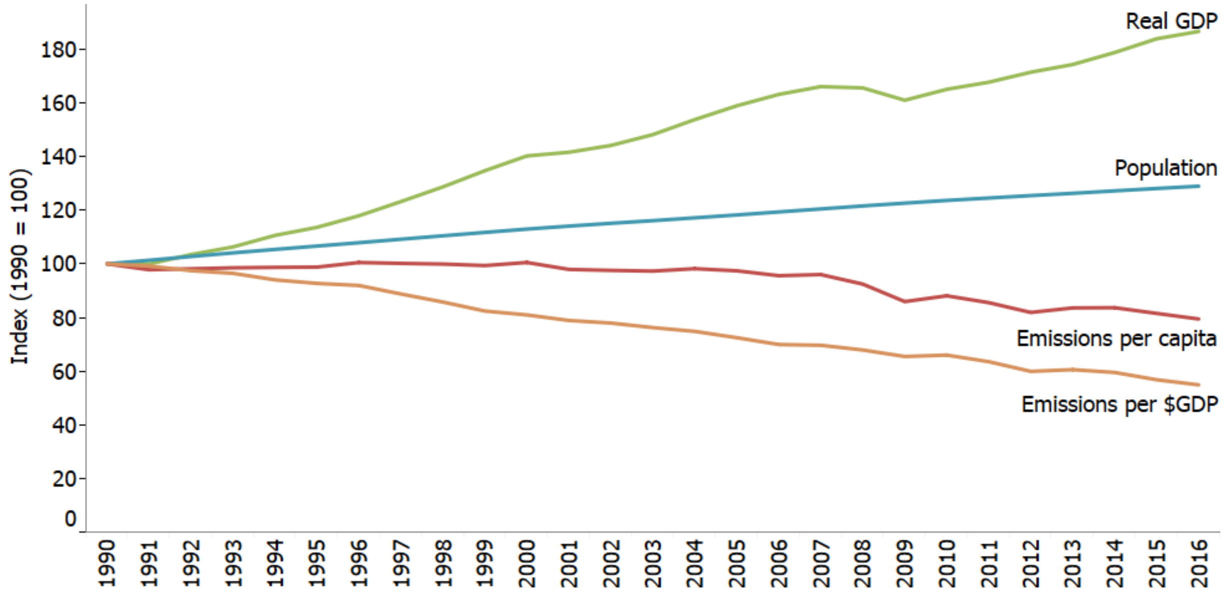
Table 2-14 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.1 percent since 1990. This rate is slightly slower than that for total energy use and fossil fuel consumption, and much slower than that for electricity use, overall gross domestic product (GDP) and national population (see Table 2-14 and Figure 2-16). These trends vary relative to 2005, when greenhouse gas emissions, total energy use 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 use and fossil fuel consumption have also decreased at slower rates than emissions since 2005, while electricity use, GDP, and national population continued to increase.

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

Variable	1990	2005	2012	2013	2014	2015	2016	Avg. Annual Change since 1990[a]	Avg. Annual Change since 2005[a]
Greenhouse Gas Emissions[b]	100	115	103	106	106	104	102	0.1%	-1.0%
Energy Use[c]	100	118	112	116	117	116	116	0.6%	-0.2%
Fossil Fuel Consumption[c]	100	119	107	110	111	110	109	0.4%	-0.7%
Electricity Use[c]	100	134	135	136	138	137	138	1.2%	0.2%
GDP[d]	100	159	171	174	179	184	187	2.4%	1.5%
Population[e]	100	118	125	126	127	128	129	1.0%	0.8%

[a] Average annual growth rate
[b] GWP-weighted values
[c] Energy-content-weighted values (EIA 2018b)
[d] GDP in chained 2009 dollars (BEA 2018)
[e] U.S. Census Bureau (2017)

Figure 2-16: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product



Source: BEA (2017), U.S. Census Bureau (2017), 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

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

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 2016),[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	2012	2013	2014	2015	2016
NO_x	**21,791**	**17,443**	**12,038**	**11,388**	**10,807**	**10,252**	**9,278**
Mobile Fossil Fuel Combustion	10,862	10,295	6,871	6,448	6,024	5,417	4,814
Stationary Fossil Fuel Combustion	10,023	5,858	3,655	3,504	3,291	3,061	2,692
Oil and Gas Activities	139	321	663	704	745	745	745
Forest Fires	81	239	276	185	185	474	474
Industrial Processes and Product Use	592	572	443	434	424	424	424
Waste Combustion	82	128	82	91	100	100	100
Grassland Fires	5	21	39	13	27	21	19
Agricultural Burning	6	6	7	7	8	8	7
Waste	+	2	2	2	2	2	2
CO	**132,926**	**75,569**	**54,109**	**48,589**	**46,875**	**54,977**	**52,990**
Mobile Fossil Fuel Combustion	119,360	58,615	36,153	34,000	31,848	29,881	27,934
Forest Fires	2,880	8,484	9,804	6,624	6,595	16,752	16,752
Stationary Fossil Fuel Combustion	5,000	4,648	4,027	3,884	3,741	3,741	3,741
Waste Combustion	978	1,403	1,318	1,632	1,947	1,947	1,947
Industrial Processes and Product Use	4,129	1,557	1,246	1,262	1,273	1,273	1,273
Oil and Gas Activities	302	318	666	723	780	780	780
Grassland Fires	84	358	657	217	442	356	324
Agricultural Burning	191	178	232	239	240	239	230
Waste	1	7	6	8	9	9	9
NMVOCs	**20,930**	**13,154**	**11,464**	**11,202**	**10,935**	**10,647**	**10,362**
Industrial Processes and Product Use	7,638	5,849	3,861	3,793	3,723	3,723	3,723
Mobile Fossil Fuel Combustion	10,932	5,724	4,243	3,924	3,605	3,318	3,032
Oil and Gas Activities	554	510	2,651	2,786	2,921	2,921	2,921
Stationary Fossil Fuel Combustion	912	716	569	539	507	507	507
Waste Combustion	222	241	94	108	121	121	121
Waste	673	114	45	51	57	57	57
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**5,876**	**5,874**	**4,357**	**3,448**	**2,457**
Stationary Fossil Fuel Combustion	18,407	11,541	5,006	5,005	3,640	2,756	1,790
Industrial Processes and Product Use	1,307	831	604	604	496	496	496
Mobile Fossil Fuel Combustion	390	180	108	108	93	93	93
Oil and Gas Activities	793	619	142	142	95	70	44
Waste Combustion	38	25	15	15	32	32	32
Waste	+	1	+	+	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 2016) except for estimates from Field Burning of Agricultural Residues.

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

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.

Electric power is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 43.8 percent in 2016. 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.