2. Trends in Greenhouse Gas Emissions

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

In 2014, total U.S. greenhouse gas emissions were 6,870.5 MMT or million metric tons carbon dioxide (CO_2) Eq. Total U.S. emissions have increased by 7.4 percent from 1990 to 2014, and emissions increased from 2013 to 2014 by 1.0 percent (70.5 MMT CO_2 Eq.). The increase in CO_2 emissions from fossil fuel combustion was a result of multiple factors, including: (1) colder winter conditions in the first quarter of 2014 resulting in an increased demand for heating fuel in the residential and commercial sectors; (2) an increase in transportation emissions resulting from an increase in vehicle miles traveled (VMT) and fuel use across on-road transportation modes; and (3) an increase in industrial production across multiple sectors resulting in slight increases in industrial sector emissions. Since 1990, U.S. emissions have increased at an average annual rate of 0.3 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 2014 were 8.6 percent below 2005 levels as shown in Table 2-1.

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

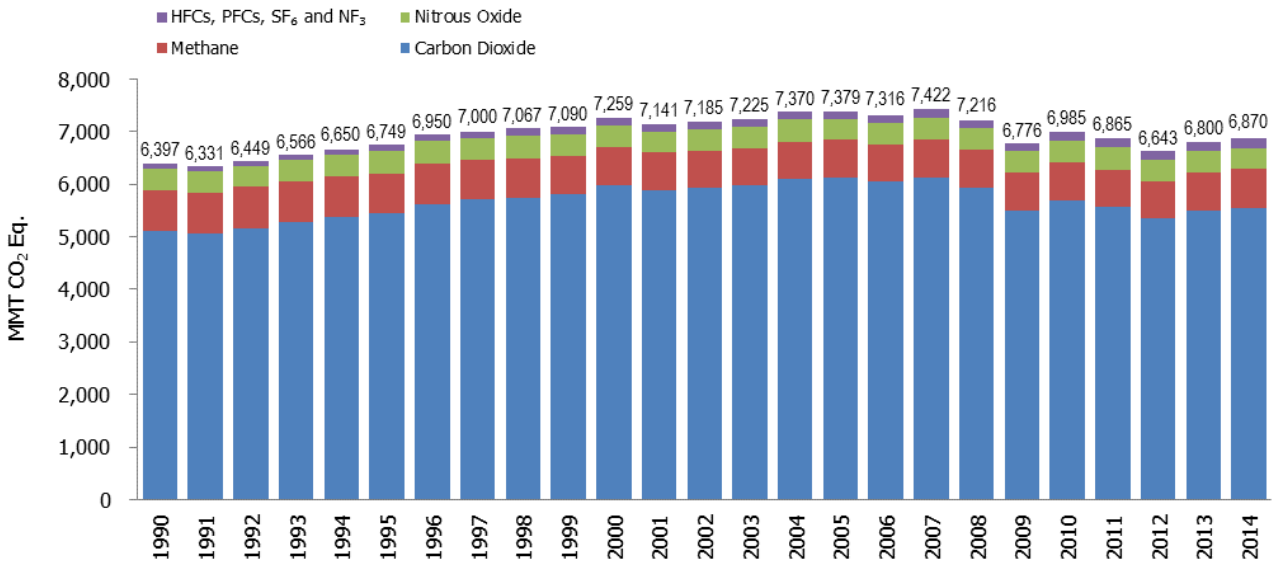


Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions Relative to the Previous Year

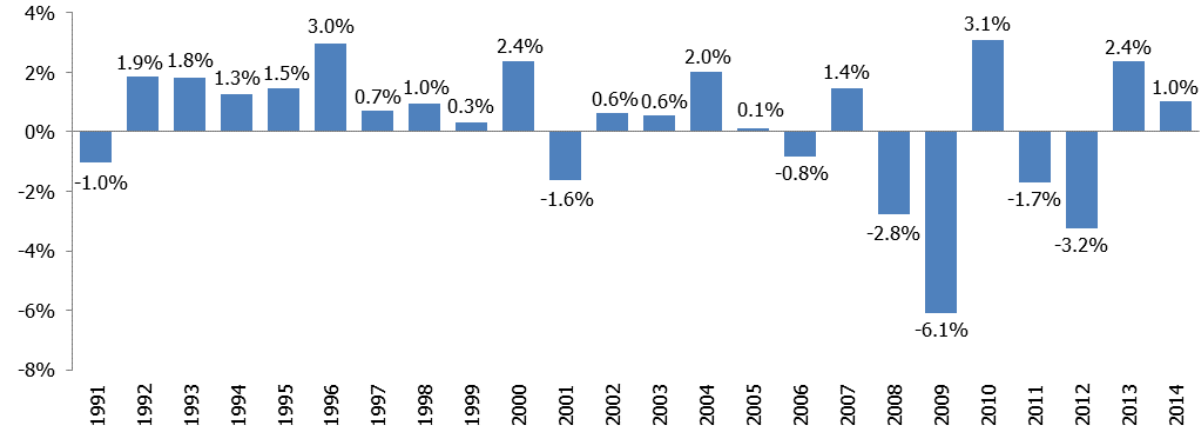
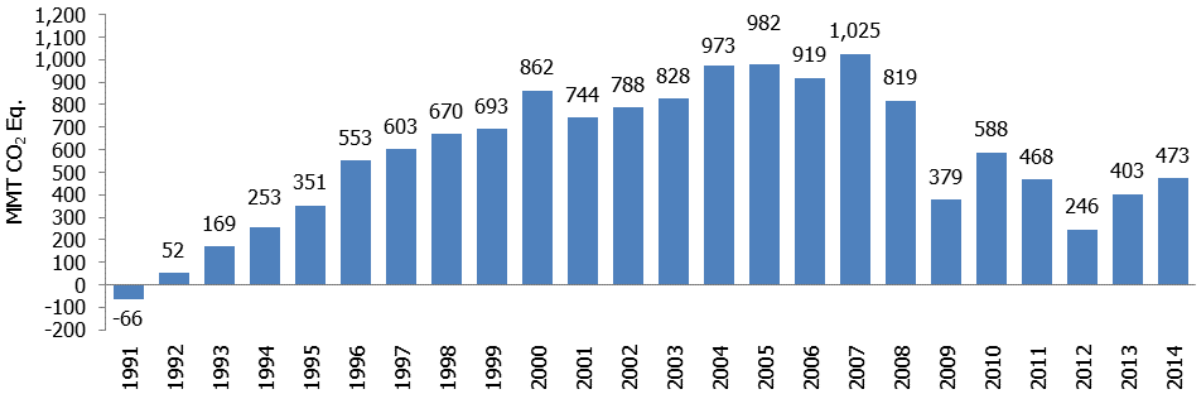


Figure 2-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)



Overall, from 1990 to 2014, total emissions of CO_2 increased by 440.9 MMT CO_2 Eq. (8.6 percent), while total emissions of methane (CH_4) decreased by 43.0 MMT CO_2 Eq. (5.6 percent), and total emissions of nitrous oxide (N_2O) decreased by 2.7 MMT CO_2 Eq. (0.7 percent). During the same period, aggregate weighted emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) rose by 78.1 MMT CO_2 Eq. (76.6 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, and landfilled yard trimmings. These were estimated to offset 11.5 percent of total emissions in 2014.

As the largest contributor to U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 76 percent of GWP-weighted emissions for the entire time series since 1990, from 74 percent of total GWP-weighted emissions in 1990 to 76 percent in 2014. Emissions from this source category grew by 9.9 percent (467.5 MMT CO_2 Eq.) from 1990 to 2014 and were responsible for most of the increase in national emissions during this period. From 2013 to 2014, these emissions increased by 1.0 percent (50.6 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, technological changes, energy fuel choices,

and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

In the longer term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs), and behavioral choices (e.g., walking, bicycling, or telecommuting to work instead of driving).

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its C intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas.

A brief discussion of the year to year variability in fuel combustion emissions is provided below, beginning with 2010.

From 2010 to 2011, CO_2 emissions from fossil fuel combustion decreased by 2.4 percent. This decrease is a result of multiple factors including: (1) a decrease in the C intensity of fuels consumed to generate electricity due to a decrease in coal consumption, with increased natural gas consumption and a significant increase in hydropower used; (2) a decrease in transportation-related energy consumption due to higher fuel costs, improvements in fuel efficiency, and a reduction in miles traveled; and (3) relatively mild winter conditions resulting in an overall decrease in energy demand in most sectors. Changing fuel prices played a role in the decreasing emissions. A significant increase in the price of motor gasoline in the transportation sector was a major factor leading to a decrease in energy consumption by 1.2 percent. In addition, an increase in the price of coal and a concurrent decrease in natural gas prices led to a 5.7 percent decrease and a 2.5 percent increase in fuel consumption of these fuels by electric generators. This change in fuel prices also reduced the carbon intensity of fuels used to produce electricity in 2011, further contributing to the decrease in fossil fuel combustion emissions.

From 2011 to 2012, CO_2 emissions from fossil fuel combustion decreased by 3.9 percent, with emissions from fossil fuel combustion at their lowest level since 1994. This decrease from 2011 to 2012 is primarily a result of the decrease in the carbon intensity of fuels used to generate electricity due to a slight increase in the price of coal, and a significant decrease in the price of natural gas. The consumption of coal used to generate electricity decreased by 12.3 percent, while consumption of natural gas for electricity generation increased by 20.4 percent. Also, emissions declined in the transportation sector largely due to a small increase in fuel efficiency across different transportation modes and limited new demand for passenger transportation. In 2012, weather conditions remained fairly constant in the summer and were much warmer in the winter compared to 2011, as cooling degree days increased by 1.7 percent while heating degree days decreased 12.6 percent. This decrease in heating degree days resulted in a decreased demand for heating fuel in the residential and commercial sector, which had a decrease in natural gas consumption of 11.7 and 8.0 percent, respectively.

From 2012 to 2013, CO_2 emissions from fossil fuel combustion increased by 2.6 percent. This increase is primarily a result of the increased energy consumption in the residential and commercial sectors, as heating degree days increased 18.5 percent in 2013 as compared to 2012. The cooler weather led to an increase of 17.1 and 12.9 percent direct use of fuels in the residential and commercial sectors, respectively. In addition, there was an increase of 1.5 and 0.8 percent in electricity consumption in the residential and commercial sectors, respectively, due to regions that heat their homes with electricity. The consumption of natural gas used to generate electricity decreased by 9.8 percent due to an increase in the price of natural gas. Electric power plants shifted some consumption from natural gas to coal, and as a result increased coal consumption to generate electricity by 4.0 percent. Lastly, industrial production increased 1.9 percent from 2012 to 2013, resulting in an increase in the in CO_2 emissions from fossil fuel combustion from the industrial sector by 3.7 percent.

From 2013 to 2014, CO_2 emissions from fossil fuel combustion increased by 1.0 percent. This increase is primarily a result of the increased energy consumption in the transportation (around 50 percent of increase), residential (around 30 percent of increase), and commercial (around 20 percent of increase) sectors. In the transportation sector, VMT increased by 1.3 percent resulting in increased fuel consumption across on-road transportation modes. Heating

degree days increased 1.9 percent in 2014 as compared to 2013, resulting in an increased demand in heating fuels for the residential and commercial sectors. The cooler weather led to an increase of 4.5 and 5.0 percent in direct use of fuels in the residential and commercial sectors, respectively. In addition, there was an increase of 0.9 and 1.1 percent in electricity consumption in the residential and commercial sectors, respectively, due to regions that heat their homes with electricity. There was also an increase in transportation emissions resulting from an increase in VMT and fuel use across on-road transportation modes in 2014. Lastly, industrial production increased 3.7 percent from 2013 to 2014, resulting in a slight increase in CO_2 emissions from fossil fuel combustion from the industrial sector by 0.1 percent. From the perspective of how these sector trends contributed to the overall 1.0 percent increase from 2013 to 2014, the residential and commercial sectors were approximately 37 percent of the annual increase, the transportation sector was 35 percent of the annual increase, and the industrial sector was just over 1 percent of the 2013 to 2014 increase in overall U.S. emissions.

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	2010	2011	2012	2013	2014
CO_2	**5,115.1**	**6,122.7**	**5,688.8**	**5,559.5**	**5,349.2**	**5,502.6**	**5,556.0**
Fossil Fuel Combustion	4,740.7	5,747.1	5,358.3	5,227.7	5,024.7	5,157.6	5,208.2
Electricity Generation	*1,820.8*	*2,400.9*	*2,258.4*	*2,157.7*	*2,022.2*	*2,038.1*	*2,039.3*
Transportation	*1,493.8*	*1,887.0*	*1,728.3*	*1,707.6*	*1,696.8*	*1,713.0*	*1,737.6*
Industrial	*842.5*	*828.0*	*775.5*	*773.3*	*782.9*	*812.2*	*813.3*
Residential	*338.3*	*357.8*	*334.6*	*326.8*	*282.5*	*329.7*	*345.1*
Commercial	*217.4*	*223.5*	*220.1*	*220.7*	*196.7*	*221.0*	*231.9*
U.S. Territories	*27.9*	*49.9*	*41.4*	*41.5*	*43.6*	*43.5*	*41.0*
Non-Energy Use of Fuels	118.1	138.9	114.1	108.5	105.6	121.7	114.3
Iron and Steel Production & Metallurgical Coke Production	99.7	66.5	55.7	59.9	54.2	52.2	55.4
Natural Gas Systems	37.7	30.1	32.4	35.7	35.2	38.5	42.4
Cement Production	33.3	45.9	31.3	32.0	35.1	36.1	38.8
Petrochemical Production	21.6	27.4	27.2	26.3	26.5	26.4	26.5
Lime Production	11.7	14.6	13.4	14.0	13.7	14.0	14.1
Other Process Uses of Carbonates	4.9	6.3	9.6	9.3	8.0	10.4	12.1
Ammonia Production	13.0	9.2	9.2	9.3	9.4	10.0	9.4
Incineration of Waste	8.0	12.5	11.0	10.5	10.4	9.4	9.4
Carbon Dioxide Consumption	1.5	1.4	4.4	4.1	4.0	4.2	4.5
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.7	4.0	4.4	4.2	4.0
Petroleum Systems	3.6	3.9	4.2	4.2	3.9	3.7	3.6
Aluminum Production	6.8	4.1	2.7	3.3	3.4	3.3	2.8
Soda Ash Production and Consumption	2.8	3.0	2.7	2.7	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.7	1.9	1.8	1.9
Titanium Dioxide Production	1.2	1.8	1.8	1.7	1.5	1.7	1.8
Glass Production	1.5	1.9	1.5	1.3	1.2	1.3	1.3
Phosphoric Acid Production	1.5	1.3	1.1	1.2	1.1	1.1	1.1
Zinc Production	0.6	1.0	1.2	1.3	1.5	1.4	1.0
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+	+	+	+	+	+	+
Wood Biomass and Ethanol Consumption[a]	*219.4*	*229.8*	*265.1*	*268.1*	*267.7*	*286.3*	*293.7*
International Bunker Fuels[b]	*103.5*	*113.1*	*117.0*	*111.7*	*105.8*	*99.8*	*103.2*
CH_4	**773.9**	**717.4**	**722.4**	**717.4**	**714.4**	**721.5**	**730.8**
Natural Gas Systems	206.8	177.3	166.2	170.1	172.6	175.6	176.1
Enteric Fermentation	164.2	168.9	171.3	168.9	166.7	165.5	164.3

Landfills	179.6	154.0	142.1	144.4	142.3	144.3	148.0
Petroleum Systems	38.7	48.8	54.1	56.3	58.4	64.7	68.1
Coal Mining	96.5	64.1	82.3	71.2	66.5	64.6	67.6
Manure Management	37.2	56.3	60.9	61.5	63.7	61.4	61.2
Wastewater Treatment	15.7	15.9	15.5	15.3	15.0	14.8	14.7
Rice Cultivation	13.1	13.0	11.9	11.8	11.9	11.9	11.9
Stationary Combustion	8.5	7.4	7.1	7.1	6.6	8.0	8.1
Abandoned Underground Coal Mines	7.2	6.6	6.6	6.4	6.2	6.2	6.3
Composting	0.4	1.9	1.8	1.9	1.9	2.0	2.1
Mobile Combustion	5.6	2.7	2.3	2.2	2.2	2.1	2.0
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Petrochemical Production	0.2	0.1	+	+	0.1	0.1	0.1
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	**406.2**	**397.6**	**410.3**	**416.5**	**409.3**	**403.4**	**403.5**
Agricultural Soil Management	303.3	297.2	320.7	323.1	323.1	318.6	318.4
Stationary Combustion	11.9	20.2	22.2	21.3	21.4	22.9	23.4
Manure Management	14.0	16.5	17.2	17.4	17.5	17.5	17.5
Mobile Combustion	41.2	34.4	23.6	22.4	20.0	18.2	16.3
Nitric Acid Production	12.1	11.3	11.5	10.9	10.5	10.7	10.9
Adipic Acid Production	15.2	7.1	4.2	10.2	5.5	4.0	5.4
Wastewater Treatment	3.4	4.3	4.5	4.7	4.8	4.8	4.8
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	1.6	1.7	1.7	1.8	1.8
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
Semiconductor Manufacture	+	0.1	0.1	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*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*
HFCs	**46.6**	**119.9**	**149.4**	**154.3**	**155.9**	**158.9**	**166.7**
Substitution of Ozone Depleting Substances[c]	0.3	99.7	141.2	145.3	150.2	154.6	161.2
HCFC-22 Production	46.1	20.0	8.0	8.8	5.5	4.1	5.0
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Magnesium Production and Processing	0.0	0.0	+	+	+	0.1	0.1
PFCs	**24.3**	**6.7**	**4.5**	**7.0**	**6.0**	**5.8**	**5.6**
Semiconductor Manufacture	2.8	3.2	2.7	3.5	3.1	2.9	3.0
Aluminum Production	21.5	3.4	1.9	3.5	2.9	3.0	2.5
SF_6	**31.1**	**14.0**	**9.5**	**10.0**	**7.6**	**7.2**	**7.3**
Electrical Transmission and Distribution	25.4	10.6	7.0	6.8	5.6	5.4	5.6
Magnesium Production and Processing	5.2	2.7	2.1	2.8	1.6	1.5	1.0
Semiconductor Manufacture	0.5	0.7	0.4	0.4	0.4	0.4	0.7
NF_3	**+**	**0.5**	**0.6**	**0.7**	**0.6**	**0.6**	**0.5**
Semiconductor Manufacture	+	0.5	0.6	0.7	0.6	0.6	0.5
Total Emissions	**6,397.1**	**7,378.8**	**6,985.5**	**6,865.4**	**6,643.0**	**6,800.0**	**6,870.5**
LULUCF Emissions[d]	**15.0**	**28.2**	**17.8**	**22.9**	**32.3**	**24.1**	**24.6**
LULUCF Total Net Flux[e]	**(753.0)**	**(726.7)**	**(784.3)**	**(784.9)**	**(782.0)**	**(783.7)**	**(787.0)**
LULUCF Sector Total[f]	**(738.0)**	**(698.5)**	**(766.4)**	**(762.0)**	**(749.7)**	**(759.6)**	**(762.5)**
Net Emissions (Sources and Sinks)	**5,659.2**	**6,680.3**	**6,219.0**	**6,103.4**	**5,893.3**	**6,040.4**	**6,108.0**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.
+ Does not exceed 0.05 MMT CO_2 Eq.
[a] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing Energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for LULUCF.
[b] Emissions from International Bunker Fuels are not included in totals.
[c] Small amounts of PFC emissions also result from this source.
[d] LULUCF emissions include the CO_2, CH_4, and N_2O emissions reported for Non-CO_2 Emissions from Forest Fires, N_2O Fluxes from Forest Soils, CO_2 Emissions from Agricultural Liming, CO_2 Emissions from Urea Fertilization, Peatlands Remaining Peatlands, and N_2O Fluxes from Settlement Soils.
[e] Net CO_2 flux 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*, *Settlements Remaining Settlements*, and *Other*. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.
[f] The LULUCF Sector Total is the net sum of all emissions (i.e., sources) of greenhouse gases to the atmosphere plus removals of CO_2 (i.e., sinks or negative emissions) from the atmosphere.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

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

Gas/Source	1990	2005	2010	2011	2012	2013	2014
CO_2	**5,115,095**	**6,122,747**	**5,688,756**	**5,559,508**	**5,349,221**	**5,502,551**	**5,556,007**
Fossil Fuel Combustion	4,740,671	5,747,142	5,358,292	5,227,690	5,024,685	5,157,583	5,208,207
Electricity Generation	*1,820,818*	*2,400,874*	*2,258,399*	*2,157,688*	*2,022,181*	*2,038,122*	*2,039,321*
Transportation	*1,493,758*	*1,887,033*	*1,728,267*	*1,707,631*	*1,696,752*	*1,713,008*	*1,737,598*
Industrial	*842,473*	*827,999*	*775,535*	*773,312*	*782,929*	*812,221*	*813,274*
Residential	*338,347*	*357,834*	*334,587*	*326,808*	*282,540*	*329,674*	*345,105*
Commercial	*217,393*	*223,480*	*220,125*	*220,749*	*196,714*	*221,030*	*231,917*
U.S. Territories	*27,882*	*49,923*	*41,379*	*41,503*	*43,569*	*43,528*	*40,991*
Non-Energy Use of Fuels	118,114	138,876	114,063	108,515	105,624	121,682	114,311
Iron and Steel Production & Metallurgical Coke Production	99,669	66,543	55,671	59,928	54,229	52,201	55,355
Natural Gas Systems	37,732	30,076	32,439	35,662	35,203	38,457	42,351
Cement Production	33,278	45,910	31,256	32,010	35,051	36,146	38,755
Petrochemical Production	21,609	27,380	27,246	26,326	26,464	26,437	26,509
Lime Production	11,700	14,552	13,381	13,981	13,715	14,045	14,125
Other Process Uses of Carbonates	4,907	6,339	9,560	9,335	8,022	10,414	12,077
Ammonia Production	13,047	9,196	9,188	9,292	9,377	9,962	9,436
Incineration of Waste	7,972	12,454	11,026	10,550	10,362	9,421	9,421
Carbon Dioxide Consumption	1,472	1,375	4,425	4,083	4,019	4,188	4,471
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	4,730	4,029	4,449	4,179	4,007
Petroleum Systems	3,553	3,927	4,154	4,192	3,876	3,693	3,567
Aluminum Production	6,831	4,142	2,722	3,292	3,439	3,255	2,833
Soda Ash Production and Consumption	2,822	2,960	2,697	2,712	2,763	2,804	2,827
Ferroalloy Production	2,152	1,392	1,663	1,735	1,903	1,785	1,914
Titanium Dioxide Production	1,195	1,755	1,769	1,729	1,528	1,715	1,755
Glass Production	1,535	1,928	1,481	1,299	1,248	1,317	1,341
Phosphoric Acid Production	1,529	1,342	1,087	1,151	1,093	1,119	1,095
Zinc Production	632	1,030	1,182	1,286	1,486	1,429	956
Lead Production	516	553	542	538	527	546	518
Silicon Carbide Production and Consumption	375	219	181	170	158	169	173
Magnesium Production and Processing	1	3	1	3	2	2	2

Wood Biomass and Ethanol Consumption[a]	*219,413*	*229,844*	*265,110*	*268,064*	*267,730*	*286,323*	*293,729*
International Bunker Fuels[b]	*103,463*	*113,139*	*116,992*	*111,660*	*105,805*	*99,763*	*103,201*
CH_4	**30,954**	**28,694**	**28,896**	**28,697**	**28,576**	**28,859**	**29,233**
Natural Gas Systems	8,270	7,093	6,647	6,803	6,906	7,023	7,045
Enteric Fermentation	6,566	6,755	6,853	6,757	6,670	6,619	6,572
Landfills	7,182	6,161	5,685	5,774	5,691	5,772	5,919
Petroleum Systems	1,550	1,953	2,163	2,251	2,335	2,588	2,726
Coal Mining	3,860	2,565	3,293	2,849	2,658	2,584	2,703
Manure Management	1,486	2,254	2,437	2,460	2,548	2,455	2,447
Wastewater Treatment	626	636	618	610	601	592	588
Rice Cultivation	525	521	474	474	476	477	476
Stationary Combustion	339	296	283	283	265	320	324
Abandoned Underground Coal Mines	288	264	263	257	249	249	253
Composting	15	75	73	75	77	81	82
Mobile Combustion	226	110	91	90	86	84	82
Field Burning of Agricultural Residues	10	8	11	11	11	11	11
Petrochemical Production	9	3	2	2	3	3	5
Ferroalloy Production	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*	*6*	*5*	*4*	*3*	*3*
N_2O	**1,363**	**1,334**	**1,377**	**1,398**	**1,373**	**1,354**	**1,354**
Agricultural Soil Management	1,018	997	1,076	1,084	1,084	1,069	1,068
Stationary Combustion	40	68	74	71	72	77	79
Manure Management	47	55	58	58	59	59	59
Mobile Combustion	138	115	79	75	67	61	55
Nitric Acid Production	41	38	39	37	35	36	37
Adipic Acid Production	51	24	14	34	19	13	18
Wastewater Treatment	11	15	15	16	16	16	16
N_2O from Product Uses	14	14	14	14	14	14	14
Composting	1	6	5	6	6	6	6
Incineration of Waste	2	1	1	1	1	1	1
Semiconductor Manufacture	+	+	+	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[c]	M	M	M	M	M	M	M
HCFC-22 Production	3	1	1	1	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+
Magnesium Production and Processing	0	0	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Semiconductor Manufacture	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M
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 and Ethanol Consumption are not included in totals.
[b] Emissions from International Bunker Fuels are not included in totals.
[c] 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 five-year period of 1990 to 2014, total emissions in the Energy, Industrial Processes and Product Use, and Agriculture sectors grew by 421.3 MMT CO_2 Eq. (7.9 percent), 38.3 MMT CO_2 Eq. (11.2 percent), and 41.6 MMT CO_2 Eq. (7.8 percent), respectively. Emissions from the Waste sector decreased by 27.9 MMT CO_2 Eq. (14.0 percent). Over the same period, estimates of net C sequestration for the Land Use, Land-Use Change, and Forestry sector (magnitude of emissions plus CO_2 removals from all LULUCF categories) increased by 24.5 MMT CO_2 Eq. (3.3 percent).

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

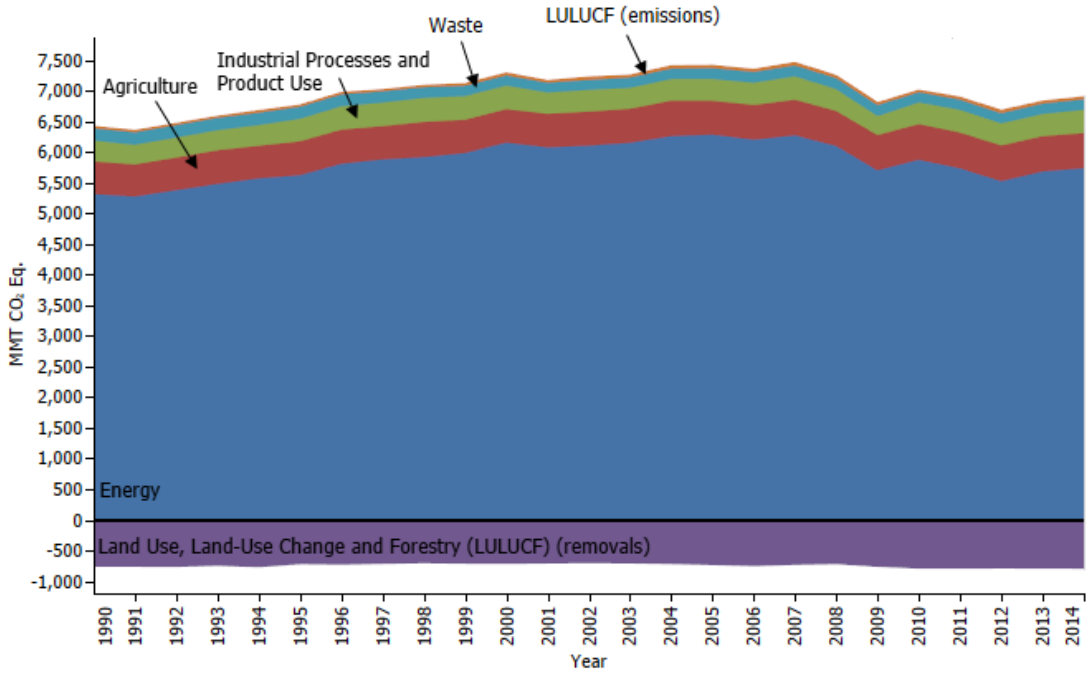


Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

Chapter/IPCC Sector	1990	2005	2010	2011	2012	2013	2014
Energy	**5,324.9**	**6,294.5**	**5,884.6**	**5,744.0**	**5,533.9**	**5,693.5**	**5,746.2**
Fossil Fuel Combustion	4,740.7	5,747.1	5,358.3	5,227.7	5,024.7	5,157.6	5,208.2
Natural Gas Systems	244.5	207.4	198.6	205.7	207.8	214.0	218.5
Non-Energy Use of Fuels	118.1	138.9	114.1	108.5	105.6	121.7	114.3
Petroleum Systems	42.3	52.8	58.2	60.5	62.2	68.4	71.7
Coal Mining	96.5	64.1	82.3	71.2	66.5	64.6	67.6
Stationary Combustion	20.4	27.6	29.2	28.4	28.0	30.9	31.5
Mobile Combustion	46.9	37.1	25.9	24.7	22.2	20.3	18.4
Incineration of Waste	8.4	12.8	11.4	10.9	10.7	9.7	9.7
Abandoned Underground Coal Mines	7.2	6.6	6.6	6.4	6.2	6.2	6.3

Industrial Processes and Product Use	**340.9**	**354.3**	**353.0**	**370.5**	**360.1**	**363.5**	**379.2**
Substitution of Ozone Depleting Substances	0.3	99.7	141.2	145.3	150.2	154.6	161.2
Iron and Steel Production & Metallurgical Coke Production	99.7	66.6	55.7	59.9	54.2	52.2	55.4
Cement Production	33.3	45.9	31.3	32.0	35.1	36.1	38.8
Petrochemical Production	21.8	27.5	27.3	26.4	26.5	26.5	26.6
Lime Production	11.7	14.6	13.4	14.0	13.7	14.0	14.1
Other Process Uses of Carbonates	4.9	6.3	9.6	9.3	8.0	10.4	12.1
Nitric Acid Production	12.1	11.3	11.5	10.9	10.5	10.7	10.9
Ammonia Production	13.0	9.2	9.2	9.3	9.4	10.0	9.4
Electrical Transmission and Distribution	25.4	10.6	7.0	6.8	5.6	5.4	5.6
Adipic Acid Production	15.2	7.1	4.2	10.2	5.5	4.0	5.4
Aluminum Production	28.3	7.6	4.6	6.8	6.4	6.2	5.4
HCFC-22 Production	46.1	20.0	8.0	8.8	5.5	4.1	5.0
Semiconductor Manufacture	3.6	4.7	4.0	5.1	4.5	4.2	4.7
Carbon Dioxide Consumption	1.5	1.4	4.4	4.1	4.0	4.2	4.5
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	4.7	4.0	4.4	4.2	4.0
Soda Ash Production and Consumption	2.8	3.0	2.7	2.7	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.7	1.9	1.8	1.9
Titanium Dioxide Production	1.2	1.8	1.8	1.7	1.5	1.7	1.8
Glass Production	1.5	1.9	1.5	1.3	1.2	1.3	1.3
Magnesium Production and Processing	5.2	2.7	2.1	2.8	1.7	1.5	1.2
Phosphoric Acid Production	1.5	1.3	1.1	1.2	1.1	1.1	1.1
Zinc Production	0.6	1.0	1.2	1.3	1.5	1.4	1.0
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	**532.0**	**552.2**	**582.3**	**583.1**	**583.3**	**575.3**	**573.6**
Agricultural Soil Management	303.3	297.2	320.7	323.1	323.1	318.6	318.4
Enteric Fermentation	164.2	168.9	171.3	168.9	166.7	165.5	164.3
Manure Management	51.1	72.9	78.1	78.9	81.2	78.9	78.7
Rice Cultivation	13.1	13.0	11.9	11.8	11.9	11.9	11.9
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Waste	**199.3**	**177.8**	**165.5**	**167.8**	**165.7**	**167.8**	**171.4**
Landfills	179.6	154.0	142.1	144.4	142.3	144.3	148.0
Wastewater Treatment	19.0	20.2	19.9	19.9	19.8	19.6	19.5
Composting	0.7	3.5	3.5	3.5	3.7	3.9	3.9
Total Emissions[a]	**6,397.1**	**7,378.8**	**6,985.5**	**6,865.4**	**6,643.0**	**6,800.0**	**6,870.5**
Land Use, Land-Use Change, and Forestry	**(738.0)**	**(698.5)**	**(766.4)**	**(762.0)**	**(749.7)**	**(759.6)**	**(762.5)**
Forest Land	(718.7)	(675.8)	(736.5)	(725.6)	(717.4)	(726.8)	(730.0)
Cropland	38.5	25.9	34.0	17.1	21.1	21.1	22.3
Grassland	26.2	39.8	32.0	43.0	43.9	44.1	44.2
Wetlands	1.1	1.1	1.0	0.9	0.8	0.8	0.8
Settlements	(59.0)	(78.2)	(83.8)	(84.8)	(85.8)	(87.1)	(88.2)
Other	(26.0)	(11.4)	(13.2)	(12.7)	(12.2)	(11.7)	(11.6)
Net Emissions (Sources and Sinks)[b]	**5,659.2**	**6,680.3**	**6,219.0**	**6,103.4**	**5,893.3**	**6,040.4**	**6,108.0**

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

[a] Total emissions without LULUCF.

[b] Net emissions with LULUCF.

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

Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2014. In 2014, approximately 82 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 18 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure 2-5 and Figure 2-6). A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (45 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: 2014 Energy Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

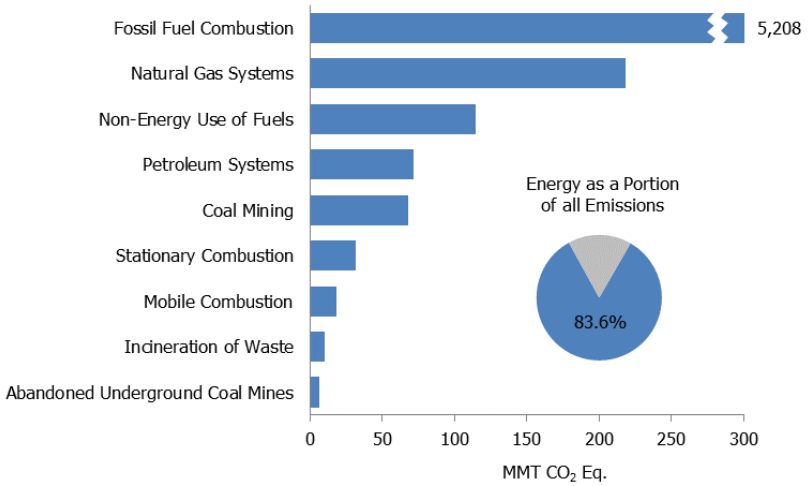


Figure 2-6: 2014 U.S. Fossil Carbon Flows (MMT CO_2 Eq.)

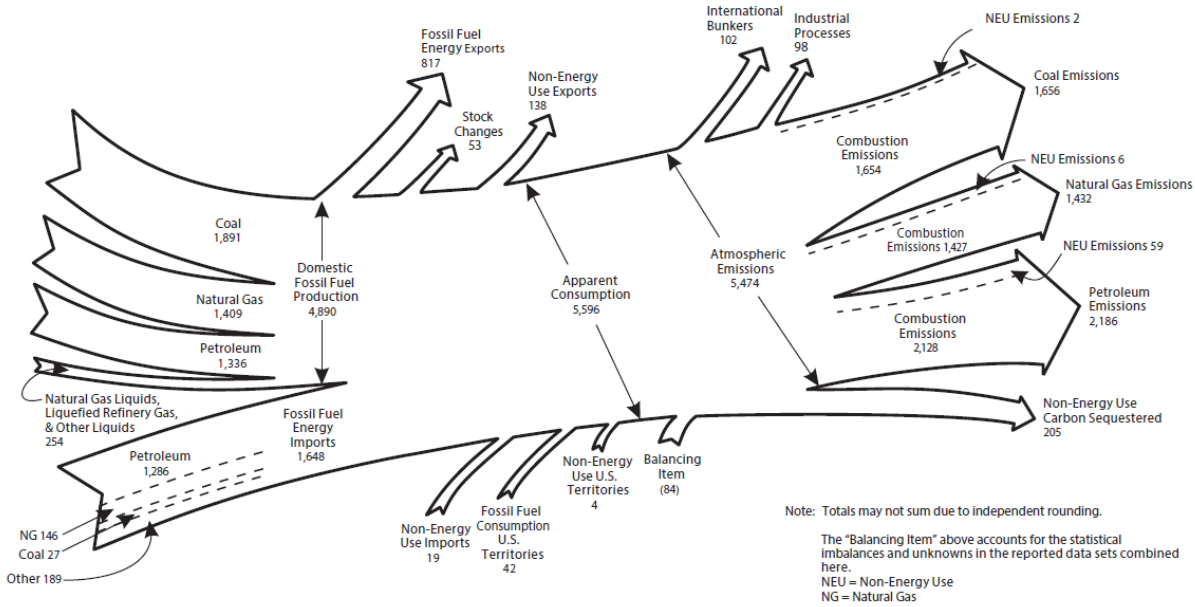


Table 2-4: Emissions from Energy (MMT CO_2 Eq.)

Gas/Source	1990	2005	2010	2011	2012	2013	2014
CO_2	**4,908.0**	**5,932.5**	**5,520.0**	**5,386.6**	**5,179.7**	**5,330.8**	**5,377.9**
Fossil Fuel Combustion	4,740.7	5,747.1	5,358.3	5,227.7	5,024.7	5,157.6	5,208.2
Electricity Generation	*1,820.8*	*2,400.9*	*2,258.4*	*2,157.7*	*2,022.2*	*2,038.1*	*2,039.3*
Transportation	*1,493.8*	*1,887.0*	*1,728.3*	*1,707.6*	*1,696.8*	*1,713.0*	*1,737.6*
Industrial	*842.5*	*828.0*	*775.5*	*773.3*	*782.9*	*812.2*	*813.3*
Residential	*338.3*	*357.8*	*334.6*	*326.8*	*282.5*	*329.7*	*345.1*
Commercial	*217.4*	*223.5*	*220.1*	*220.7*	*196.7*	*221.0*	*231.9*
U.S. Territories	*27.9*	*49.9*	*41.4*	*41.5*	*43.6*	*43.5*	*41.0*
Non-Energy Use of Fuels	118.1	138.9	114.1	108.5	105.6	121.7	114.3
Natural Gas Systems	37.7	30.1	32.4	35.7	35.2	38.5	42.4
Incineration of Waste	8.0	12.5	11.0	10.5	10.4	9.4	9.4
Petroleum Systems	3.6	3.9	4.2	4.2	3.9	3.7	3.6
Biomass-Wood[a]	*215.2*	*206.9*	*192.5*	*195.2*	*194.9*	*211.6*	*217.7*
International Bunker Fuels[b]	*103.5*	*113.1*	*117.0*	*111.7*	*105.8*	*99.8*	*103.2*
Biomass-Ethanol[a]	*4.2*	*22.9*	*72.6*	*72.9*	*72.8*	*74.7*	*76.1*
CH_4	**363.3**	**307.0**	**318.5**	**313.3**	**312.5**	**321.2**	**328.3**
Natural Gas Systems	206.8	177.3	166.2	170.1	172.6	175.6	176.1
Petroleum Systems	38.7	48.8	54.1	56.3	58.4	64.7	68.1
Coal Mining	96.5	64.1	82.3	71.2	66.5	64.6	67.6
Stationary Combustion	8.5	7.4	7.1	7.1	6.6	8.0	8.1
Abandoned Underground Coal Mines	7.2	6.6	6.6	6.4	6.2	6.2	6.3
Mobile Combustion	5.6	2.7	2.3	2.2	2.2	2.1	2.0
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**53.6**	**55.0**	**46.1**	**44.0**	**41.7**	**41.4**	**40.0**
Stationary Combustion	11.9	20.2	22.2	21.3	21.4	22.9	23.4
Mobile Combustion	41.2	34.4	23.6	22.4	20.0	18.2	16.3
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*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*
Total	**5,324.9**	**6,294.5**	**5,884.6**	**5,744.0**	**5,533.9**	**5,693.5**	**5,746.2**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for LULUCF.

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

Note: Totals may not sum due to independent rounding.

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

2-5 and Figure 2-7 summarize CO_2 emissions from fossil fuel combustion by end-use sector. Figure 2-8 further describes the total emissions from fossil fuel combustion, separated by end-use sector, including CH_4 and N_2O in addition to CO_2.

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

End-Use Sector	1990	2005	2010	2011	2012	2013	2014
Transportation	**1,496.8**	**1,891.8**	**1,732.7**	**1,711.9**	**1,700.6**	**1,717.0**	**1,741.7**
Combustion	1,493.8	1,887.0	1,728.3	1,707.6	1,696.8	1,713.0	1,737.6
Electricity	3.0	4.7	4.5	4.3	3.9	4.0	4.1
Industrial	**1,529.2**	**1,564.6**	**1,416.5**	**1,398.0**	**1,375.7**	**1,407.0**	**1,406.8**
Combustion	842.5	828.0	775.5	773.3	782.9	812.2	813.3
Electricity	686.7	736.6	641.0	624.7	592.8	594.7	593.6
Residential	**931.4**	**1,214.1**	**1,174.6**	**1,117.5**	**1,007.8**	**1,064.6**	**1,080.3**
Combustion	338.3	357.8	334.6	326.8	282.5	329.7	345.1
Electricity	593.0	856.3	840.0	790.7	725.3	734.9	735.2
Commercial	**755.4**	**1,026.8**	**993.0**	**958.8**	**897.0**	**925.5**	**938.4**
Combustion	217.4	223.5	220.1	220.7	196.7	221.0	231.9
Electricity	538.0	803.3	772.9	738.0	700.3	704.5	706.5
U.S. Territories[a]	**27.9**	**49.9**	**41.4**	**41.5**	**43.6**	**43.5**	**41.0**
Total	**4,740.7**	**5,747.1**	**5,358.3**	**5,227.7**	**5,024.7**	**5,157.6**	**5,208.2**
Electricity Generation	**1,820.8**	**2,400.9**	**2,258.4**	**2,157.7**	**2,022.2**	**2,038.1**	**2,039.3**

[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 electricity generation are allocated based on aggregate national electricity consumption by each end-use sector. Totals may not sum due to independent rounding.

Figure 2-7: 2014 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO_2 Eq.)

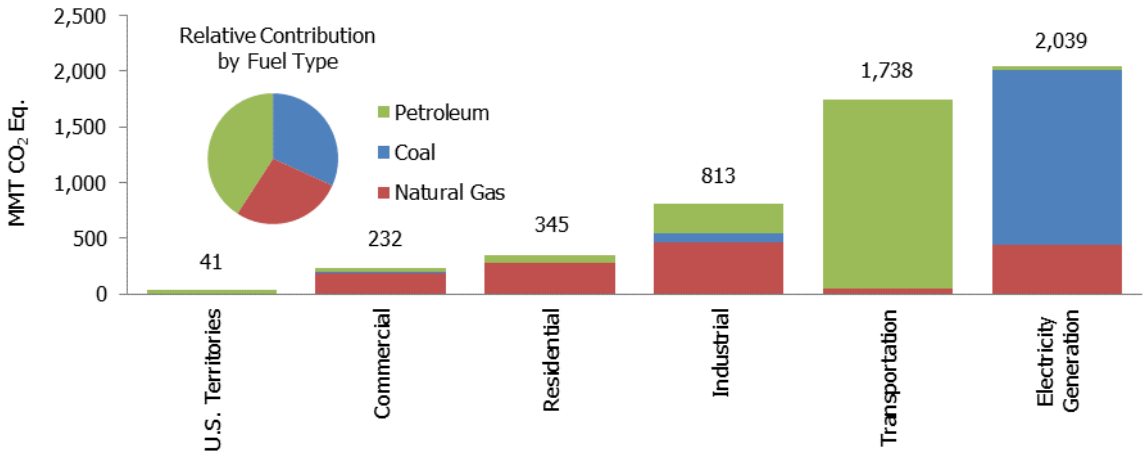
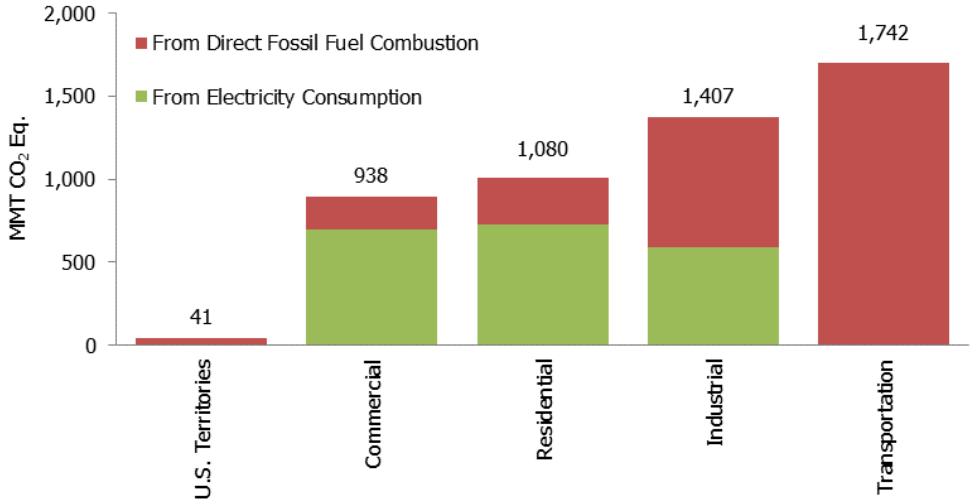


Figure 2-8: 2014 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion (MMT CO_2 Eq.)



The main driver of emissions in the Energy sector is CO_2 from fossil fuel combustion. Electricity generation is the largest emitter of CO_2, and electricity generators consumed 34 percent of U.S. energy from fossil fuels and emitted 39 percent of the CO_2 from fossil fuel combustion in 2014. Electricity generation emissions can also be allocated to the end-use sectors that are consuming that electricity, as presented in Table 2-5. The transportation end-use sector accounted for 1,741.7 MMT CO_2 Eq. in 2014 or approximately 33 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 21 and 18 percent, respectively, of CO_2 emissions from fossil fuel combustion. Both of these end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing 68 and 75 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the twenty five-year period from 1990 through 2014 included the following:

- Total CO_2 emissions from fossil fuel combustion increased from 4,740.7 MMT CO_2 Eq. in 1990 to 5,208.2 MMT CO_2 Eq. in 2014 – a 9.9 percent total increase over the twenty five-year period. From 2013 to 2014, these emissions increased by 50.6 MMT CO_2 Eq. (1.0 percent).
- Methane emissions from natural gas systems and petroleum systems (combined here) decreased very slightly from 245.5 MMT CO_2 Eq. in 1990 to 244.3 MMT CO_2 Eq. (1.2 MMT CO_2 Eq. or less than 1 percent) from 1990 to 2014. Natural gas systems CH_4 emissions decreased by 30.6 MMT CO_2 Eq. (14.8 percent) since 1990, largely due to a decrease in emissions from transmission, storage, and distribution. The decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and fugitives). The decrease in distribution emissions is largely attributed to increased use of plastic piping, which has lower emissions than other pipe materials, and station upgrades at metering and regulating (M&R) stations. Petroleum systems CH_4 emissions increased by 29.4 MMT CO_2 Eq. (or 76 percent) since 1990. This increase is due primarily to increases in emissions from production equipment.
- Carbon dioxide emissions from non-energy uses of fossil fuels decreased by 3.8 MMT CO_2 Eq. (3.2 percent) from 1990 through 2014. Emissions from non-energy uses of fossil fuels were 114.3 MMT CO_2 Eq. in 2014, 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 11.5 MMT CO_2 Eq. (96.4 percent) from 1990 through 2014. 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 24.9 MMT CO_2 Eq. (60.4 percent) from 1990 through 2014, 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 (9.4 MMT CO_2 Eq. in 2014) increased by 1.4 MMT CO_2 Eq. (18.2 percent) from 1990 through 2014, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

The increase in CO_2 emissions from fossil fuel combustion in 2014 was a result of multiple factors, including: (1) colder winter conditions in the first quarter of 2014, which resulted in an increased demand for heating fuel in the residential and commercial sectors; (2) an increase in industrial production across multiple sectors, resulting in slight increases in industrial sector emissions;[1] and (3) an increase in transportation emissions resulting from an increase in VMT and fuel use across on-road transportation modes.

Industrial Processes and Product Use

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

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production, urea consumption, lime production, other process uses of carbonates (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, zinc production, and N_2O from product uses (see Figure 2-9). Industrial processes also release HFCs, PFCs, SF_6, and NF_3. In addition to their use as substitutes for ozone depleting substances (ODS), fluorinated compounds such as HFCs, PFCs, SF_6, NF_3, and others are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

[1] Further details on industrial sector combustion emissions are provided by EPA's GHGRP. See <http://ghgdata.epa.gov/ghgp/main.do>.

Figure 2-9: 2014 Industrial Processes and Product Use Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

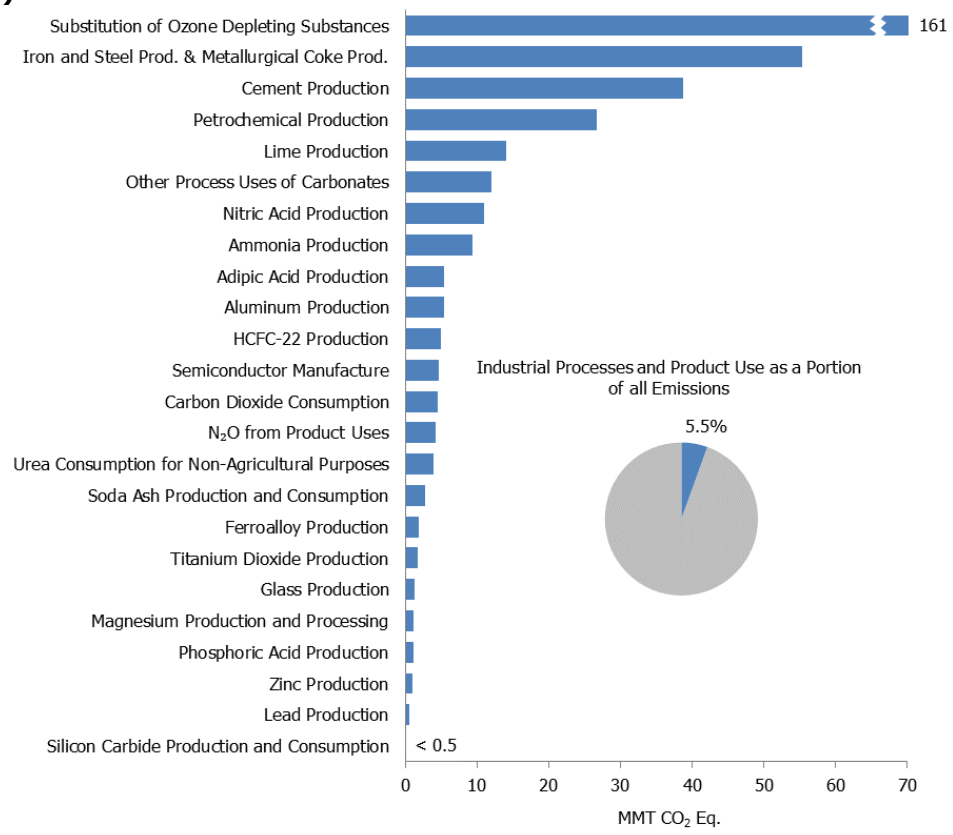


Table 2-6: Emissions from Industrial Processes and Product Use (MMT CO_2 Eq.)

Gas/Source	1990	2005	2010	2011	2012	2013	2014
CO_2	**207.1**	**190.3**	**168.8**	**172.9**	**169.5**	**171.7**	**178.1**
Iron and Steel Production & Metallurgical Coke Production	99.7	66.5	55.7	59.9	54.2	52.2	55.4
Iron and Steel Production	*97.2*	*64.5*	*53.6*	*58.5*	*53.7*	*50.4*	*53.4*
Metallurgical Coke Production	*2.5*	*2.0*	*2.1*	*1.4*	*0.5*	*1.8*	*1.9*
Cement Production	33.3	45.9	31.3	32.0	35.1	36.1	38.8
Petrochemical Production	21.6	27.4	27.2	26.3	26.5	26.4	26.5
Lime Production	11.7	14.6	13.4	14.0	13.7	14.0	14.1
Other Process Uses of Carbonates	4.9	6.3	9.6	9.3	8.0	10.4	12.1
Ammonia Production	13.0	9.2	9.2	9.3	9.4	10.0	9.4
Carbon Dioxide Consumption	1.5	1.4	4.4	4.1	4.0	4.2	4.5
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.7	4.0	4.4	4.2	4.0
Aluminum Production	6.8	4.1	2.7	3.3	3.4	3.3	2.8
Soda Ash Production and Consumption	2.8	3.0	2.7	2.7	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.7	1.9	1.8	1.9
Titanium Dioxide Production	1.2	1.8	1.8	1.7	1.5	1.7	1.8
Glass Production	1.5	1.9	1.5	1.3	1.2	1.3	1.3
Phosphoric Acid Production	1.5	1.3	1.1	1.2	1.1	1.1	1.1
Zinc Production	0.6	1.0	1.2	1.3	1.5	1.4	1.0
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+	+	+	+	+	+	+

CH_4	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**
Petrochemical Production	0.2	0.1	+	+	0.1	0.1	0.1
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Iron and Steel Production	+	+	+	+	+	+	+
Metallurgical Coke Production	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
N_2O	**31.6**	**22.8**	**20.1**	**25.5**	**20.4**	**19.1**	**20.8**
Nitric Acid Production	12.1	11.3	11.5	10.9	10.5	10.7	10.9
Adipic Acid Production	15.2	7.1	4.2	10.2	5.5	4.0	5.4
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Semiconductor Manufacturing	+	0.1	0.1	0.2	0.2	0.2	0.2
HFCs	**46.6**	**119.9**	**149.4**	**154.3**	**155.9**	**158.9**	**166.7**
Substitution of Ozone Depleting Substances[a]	0.3	99.7	141.2	145.3	150.2	154.6	161.2
HCFC-22 Production	46.1	20.0	8.0	8.8	5.5	4.1	5.0
Semiconductor Manufacturing	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Magnesium Production and Processing	0.0	0.0	+	+	+	0.1	0.1
PFCs	**24.3**	**6.7**	**4.5**	**7.0**	**6.0**	**5.8**	**5.6**
Semiconductor Manufacturing	2.8	3.2	2.7	3.5	3.1	2.9	3.0
Aluminum Production	21.5	3.4	1.9	3.5	2.9	3.0	2.5
SF_6	**31.1**	**14.0**	**9.5**	**10.0**	**7.6**	**7.2**	**7.3**
Electrical Transmission and Distribution	25.4	10.6	7.0	6.8	5.6	5.4	5.6
Magnesium Production and Processing	5.2	2.7	2.1	2.8	1.6	1.5	1.0
Semiconductor Manufacturing	0.5	0.7	0.4	0.4	0.4	0.4	0.7
NF_3	**+**	**0.5**	**0.6**	**0.7**	**0.6**	**0.6**	**0.5**
Semiconductor Manufacturing	+	0.5	0.6	0.7	0.6	0.6	0.5
Total	**340.9**	**354.3**	**353.0**	**370.5**	**360.1**	**363.5**	**379.2**

+ 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 11.2 percent from 1990 to 2014. Significant trends in emissions from IPPU source categories over the twenty five-year period from 1990 through 2014 included the following:

- Hydrofluorocarbon emissions from ODS substitutes have been increasing from small amounts in 1990 to 161.2 MMT CO_2 Eq. in 2014. 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 increased by 6.0 percent to 55.4 MMT CO_2 Eq. from 2013 to 2014, and have declined overall by 44.3 MMT CO_2 Eq. (44.5 percent) from 1990 through 2014, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- Carbon dioxide emissions from ammonia production (9.4 MMT CO_2 Eq. in 2014) decreased by 3.6 MMT CO_2 Eq. (27.7 percent) since 1990. Ammonia production relies on natural gas as both a feedstock and a fuel, and as such, market fluctuations and volatility in natural gas prices affect the production of ammonia.
- Urea consumption for non-agricultural purposes (4.0 MMT CO_2 Eq. in 2014) increased by 0.2 MMT CO_2 Eq. (5.9 percent) since 1990. From 1990 to 2007, emissions increased by 31 percent to a peak of 4.9 MMT CO_2 Eq., before decreasing by 19 percent to 2014 levels.

- In 2014, N_2O emissions from product uses constituted 1.0 percent of U.S. N_2O emissions. From 1990 to 2014, emissions from this source category decreased by 0.4 percent, though slight increases occurred in intermediate years.
- Nitrous oxide emissions from adipic acid production were 5.4 MMT CO_2 Eq. in 2014, 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 64.2 percent since 1990 and by 67.8 percent since a peak in 1995.
- PFC emissions from aluminum production decreased by 88.2 percent (18.9 MMT CO_2 Eq.) from 1990 to 2014, 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, and field burning of agricultural residues.

In 2014, agricultural activities were responsible for emissions of 573.6 MMT CO_2 Eq., or 8.3 percent of total U.S. greenhouse gas emissions. Methane and nitrous oxide were the primary greenhouse gases emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented about 22.5 percent and 8.4 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2014. Agricultural soil management activities, such as fertilizer use and other cropping practices, were the largest source of U.S. N_2O emissions in 2014, accounting for 78.9 percent. Figure 2-10 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

Figure 2-10: 2014 Agriculture Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

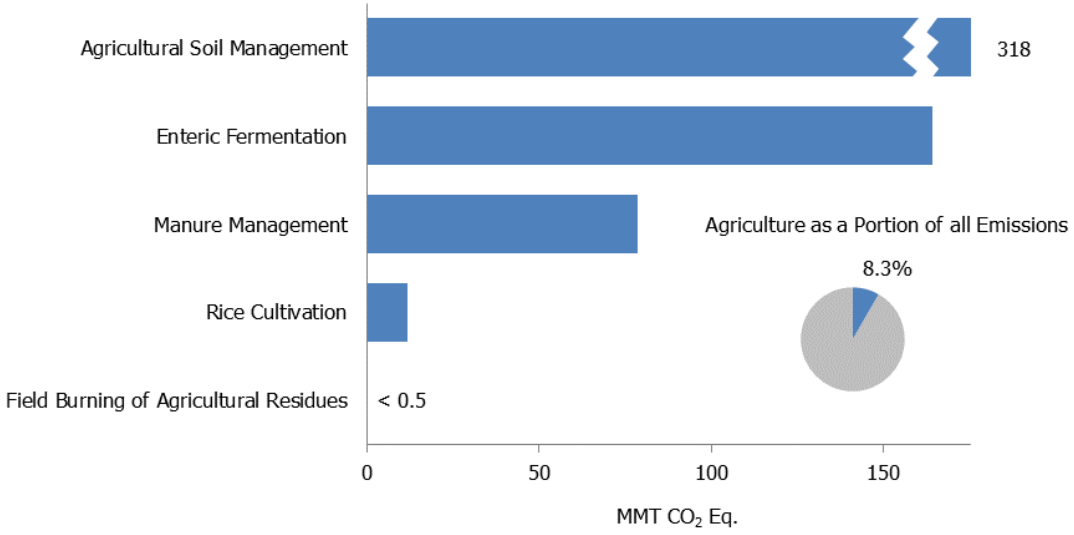


Table 2-7: Emissions from Agriculture (MMT CO_2 Eq.)

Gas/Source	1990	2005	2010	2011	2012	2013	2014
CH_4	**214.7**	**238.4**	**244.4**	**242.5**	**242.6**	**239.0**	**237.7**
Enteric Fermentation	164.2	168.9	171.3	168.9	166.7	165.5	164.3
Manure Management	37.2	56.3	60.9	61.5	63.7	61.4	61.2
Rice Cultivation	13.1	13.0	11.9	11.8	11.9	11.9	11.9
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
N_2O	**317.4**	**313.8**	**338.0**	**340.6**	**340.7**	**336.2**	**336.0**
Agricultural Soil Management	303.3	297.2	320.7	323.1	323.1	318.6	318.4
Manure Management	14.0	16.5	17.2	17.4	17.5	17.5	17.5
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**532.0**	**552.2**	**582.3**	**583.1**	**583.3**	**575.3**	**573.6**

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 produced approximately 78.9 percent of N_2O emissions in the United States in 2014. Estimated emissions from this source in 2014 were 318.4 MMT CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2014, although overall emissions were 5.0 percent higher in 2014 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 second largest anthropogenic source of CH_4 emissions in the United States. In 2014, enteric fermentation CH_4 emissions were 164.3 MMT CO_2 Eq. (22.5 percent of total CH_4 emissions), which represents an increase of 0.1 MMT CO_2 Eq. (0.1 percent) since 1990. This increase in emissions from 1990 to 2014 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 underwent increases and the literature for dairy cow diets indicated a trend toward a decrease in feed digestibility for those years. Emissions decreased again from 2008 to 2014 as beef cattle populations again decreased.
- Overall, emissions from manure management increased 53.8 percent between 1990 and 2014. This encompassed an increase of 64.7 percent for CH_4, from 37.2 MMT CO_2 Eq. in 1990 to 61.2 MMT CO_2 Eq. in 2014; and an increase of 24.9 percent for N_2O, from 14.0 MMT CO_2 Eq. in 1990 to 17.5 MMT CO_2 Eq. in 2014. The majority of the increase observed in CH_4 resulted from swine and dairy cow manure, where emissions increased 44 and 118 percent, respectively, from 1990 to 2014. From 2013 to 2014, there was a 0.3 percent decrease 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 alter the background C fluxes between biomass, soils, and the atmosphere. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in a net removal of CO_2 (sequestration of C) in the United States. Forests (including vegetation, soils, and harvested wood) accounted for 87 percent of total 2014 CO_2 removals, urban trees accounted for 11 percent, landfilled yard trimmings and food scraps accounted for 1.4 percent, and mineral and organic soil carbon stock changes from *Cropland Remaining Cropland* accounted for 1.0 percent of the total CO_2 removals in 2014. The net forest sequestration is a result of net forest growth, increasing forest area, and a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth and increased urban forest size. In agricultural soils, mineral and organic soils sequester approximately as much C as is emitted

from these soils through liming and urea fertilization. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming and food scraps carbon in landfills.

LULUCF activities in 2014 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 787.0 MMT CO_2 Eq. (Table 2-3).[2] This represents an offset of approximately 11.5 percent of total (i.e., gross) greenhouse gas emissions in 2014. Emissions from LULUCF activities in 2014 are 24.6 MMT CO_2 Eq. and represent 0.4 percent of total greenhouse gas emissions.[3] Between 1990 and 2014, total C sequestration in the LULUCF sector increased by 4.5 percent, primarily due to an increase in the rate of net C accumulation in forest and urban tree C stocks.

Carbon dioxide removals are presented in Table 2-8 along with CO_2, CH_4, and N_2O emissions for LULUCF source categories. Liming and urea fertilization resulted in CO_2 emissions of 8.7 MMT CO_2 Eq. in 2014, an increase of about 22.2 percent relative to 1990. Lands undergoing peat extraction (i.e., *Peatlands Remaining Peatlands*) resulted in CO_2 emissions of 0.8 MMT CO_2 Eq. and CH_4 and N_2O emissions of less than 0.05 MMT CO_2 Eq. each. Nitrous oxide emissions from the application of synthetic fertilizers to forest soils have increased from 0.1 MMT CO_2 Eq. in 1990 to 0.5 MMT CO_2 Eq. in 2014. Settlement soils in 2014 resulted in N_2O emissions of 2.4 MMT CO_2 Eq., a 78.4 percent increase relative to 1990. Emissions from forest fires in 2014 resulted in CH_4 emissions of 7.3 MMT CO_2 and in N_2O emissions of 4.8 MMT CO_2 (see Table 2-8).

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

Gas/Land-Use Category	1990	2005	2010	2011	2012	2013	2014
Net CO_2 Flux[a]	**(753.0)**	**(726.7)**	**(784.3)**	**(784.9)**	**(782.0)**	**(783.7)**	**(787.0)**
Forest Land Remaining Forest Land[b]	(723.5)	(691.9)	(742.0)	(736.7)	(735.8)	(739.1)	(742.3)
Land Converted to Forest Land	(0.7)	(0.8)	(0.4)	(0.4)	(0.4)	(0.3)	(0.3)
Cropland Remaining Cropland	(34.3)	(14.1)	1.8	(12.5)	(11.2)	(9.3)	(8.4)
Land Converted to Cropland	65.7	32.2	23.7	21.6	22.0	22.1	22.1
Grassland Remaining Grassland	(12.9)	(3.3)	(7.3)	3.1	3.6	3.8	3.8
Land Converted to Grassland	39.1	43.1	39.3	39.9	40.4	40.4	40.4
Settlements Remaining Settlements	(60.4)	(80.5)	(86.1)	(87.3)	(88.4)	(89.5)	(90.6)
Other: Landfilled Yard Trimmings and Food Scraps	(26.0)	(11.4)	(13.2)	(12.7)	(12.2)	(11.7)	(11.6)
CO_2	**8.1**	**9.0**	**9.6**	**8.9**	**11.0**	**9.0**	**9.5**
Cropland Remaining Cropland: CO_2 Emissions from Urea Fertilization	2.4	3.5	3.8	4.1	4.2	4.3	4.5
Cropland Remaining Cropland: CO_2 Emissions from Liming	4.7	4.3	4.8	3.9	6.0	3.9	4.1
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	1.1	1.1	1.0	0.9	0.8	0.8	0.8
CH_4	**3.3**	**9.9**	**3.3**	**6.6**	**11.1**	**7.3**	**7.4**
Forest Land Remaining Forest Land: Non-CO_2 Emissions from Forest Fires	3.3	9.9	3.3	6.6	11.1	7.3	7.3
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
N_2O	**3.6**	**9.3**	**5.0**	**7.3**	**10.3**	**7.7**	**7.7**
Forest Land Remaining Forest Land: Non-CO_2 Emissions from Forest Fires	2.2	6.5	2.2	4.4	7.3	4.8	4.8
Settlements Remaining Settlements: N_2O Fluxes from Settlement Soils[c]	1.4	2.3	2.4	2.5	2.5	2.4	2.4
Forest Land Remaining Forest Land: N_2O Fluxes from Forest Soils[d]	0.1	0.5	0.5	0.5	0.5	0.5	0.5

[2] Net CO_2 flux 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, Settlements Remaining Settlements,* and *Other.*

[3] LULUCF emissions include the CO_2, CH_4, and N_2O emissions reported for Non-CO_2 Emissions from Forest Fires, N_2O Fluxes from Forest Soils, CO_2 Emissions from Liming, CO_2 Emissions from Urea Fertilization, Peatlands Remaining Peatlands, and N_2O Fluxes from Settlement Soils.

Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
LULUCF Emissions[e]	**15.0**	**28.2**	**17.8**	**22.9**	**32.3**	**24.1**	**24.6**
LULUCF Total Net Flux[a]	**(753.0)**	**(726.7)**	**(784.3)**	**(784.9)**	**(782.0)**	**(783.7)**	**(787.0)**
LULUCF Sector Total[f]	**(738.0)**	**(698.5)**	**(766.4)**	**(762.0)**	**(749.7)**	**(759.6)**	**(762.5)**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Net CO_2 flux 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, Settlements Remaining Settlements,* and *Other.*

[b] Includes the effects of net additions to stocks of carbon stored in forest ecosystem pools and harvested wood products.

[c] Estimates include emissions from N fertilizer additions on both *Settlements Remaining Settlements* and *Land Converted to Settlements.*

[d] Estimates include emissions from N fertilizer additions on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*.

[e] LULUCF emissions include the CO_2, CH_4, and N_2O emissions reported for Non-CO_2 Emissions from Forest Fires, N_2O Fluxes from Forest Soils, CO_2 Emissions from Liming, CO_2 Emissions from Urea Fertilization, Peatlands Remaining Peatlands, and N_2O Fluxes from Settlement Soils.

[f] The LULUCF Sector Total is the net sum of all emissions (i.e., sources) of greenhouse gases to the atmosphere plus removals of CO_2 (i.e., sinks or negative emissions) from the atmosphere.

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

Other significant trends from 1990 to 2014 in emissions from LULUCF categories include:

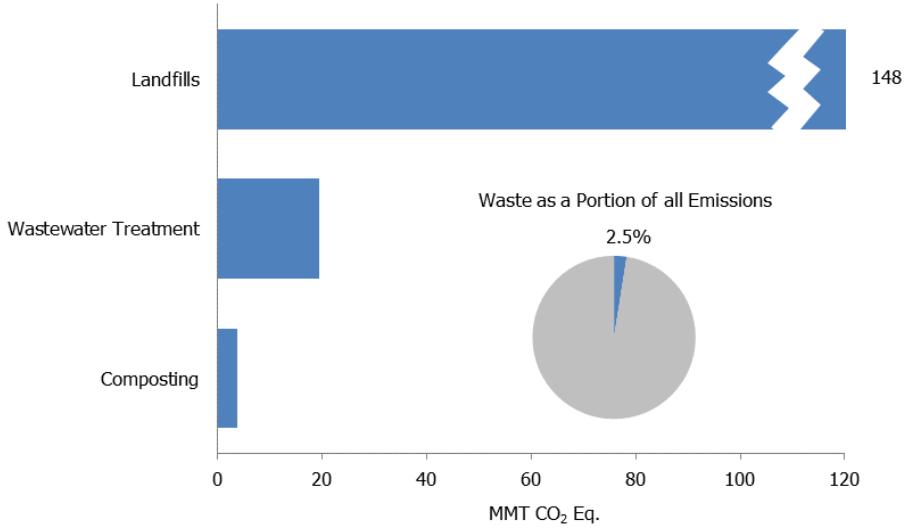
- Annual C sequestration by forest land (i.e., annual C stock accumulation in the five C pools for *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*) has increased by approximately 3 percent. This is primarily due to increased forest management and the effects of previous reforestation. The increase in intensive forest management resulted in higher growth rates and higher biomass density. The tree planting and conservation efforts of the 1970s and 1980s continue to have a significant impact on sequestration rates. Finally, the forested area in the United States increased over the past twenty five years, although only at an average rate of 0.1 percent per year.
- Annual C sequestration by urban trees has increased by 50.0 percent over the period from 1990 to 2014. This is primarily due to an increase in urbanized land area in the United States.
- Annual C sequestration in landfilled yard trimmings and food scraps has decreased by 55.4 percent since 1990. Food scrap generation has grown by 55 percent since 1990, and though the proportion of food scraps discarded in landfills has decreased slightly from 82 percent in 1990 to 76 percent in 2014, the tonnage disposed in landfills has increased considerably (by 45 percent). Overall, the decrease in the landfill disposal rate of yard trimmings has more than compensated for the increase in food scrap disposal in landfills.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-11). In 2014, landfills were the third-largest source of U.S. anthropogenic CH_4 emissions, accounting for 20.2 percent of total U.S. CH_4 emissions.[4] Additionally, wastewater treatment accounts for 11.4 percent of Waste emissions, 2.0 percent of U.S. CH_4 emissions, and 1.2 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2014, and resulted in emissions of 3.9 MMT CO_2 Eq. in 2014. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-9.

[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.

Figure 2-11: 2014 Waste Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)



Overall, in 2014, waste activities generated emissions of 171.4 MMT CO_2 Eq., or 2.5 percent of total U.S. greenhouse gas emissions.

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

Gas/Source	1990	2005	2010	2011	2012	2013	2014
CH_4	**195.6**	**171.8**	**159.4**	**161.5**	**159.2**	**161.1**	**164.7**
Landfills	179.6	154.0	142.1	144.4	142.3	144.3	148.0
Wastewater Treatment	15.7	15.9	15.5	15.3	15.0	14.8	14.7
Composting	0.4	1.9	1.8	1.9	1.9	2.0	2.1
N_2O	**3.7**	**6.0**	**6.1**	**6.4**	**6.5**	**6.6**	**6.7**
Wastewater Treatment	3.4	4.3	4.5	4.7	4.8	4.8	4.8
Composting	0.3	1.7	1.6	1.7	1.7	1.8	1.8
Total	**199.3**	**177.8**	**165.5**	**167.8**	**165.7**	**167.8**	**171.4**

Note: Totals may not sum due to independent rounding.

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

- From 1990 to 2014, net CH_4 emissions from landfills decreased by 31.6 MMT CO_2 Eq. (17.6 percent), with small increases occurring in interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted as well as reductions in the amount of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in municipal solid waste (MSW) landfills over the time series,[5] which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.
- Combined CH_4 and N_2O emissions from composting have generally increased since 1990, from 0.7 MMT CO_2 Eq. to 3.9 MMT CO_2 Eq. in 2014, which represents slightly more than a five-fold increase over the time series. The growth in composting since the 1990s is attributable to primarily two factors: (1) steady growth in population and residential housing, and (2) the enactment of legislation by state and local governments that discouraged the disposal of yard trimmings in landfills.
- From 1990 to 2014, CH_4 and N_2O emissions from wastewater treatment decreased by 1.0 MMT CO_2 Eq. (6.1 percent) and increased by 1.5 MMT CO_2 Eq. (44.1 percent), respectively. Methane emissions from

[5] The CO_2 produced from combusted landfill CH_4 at landfills is not counted in national inventories as it is considered part of the natural C cycle of decomposition.

domestic wastewater treatment have decreased since 1999 due to decreasing percentages of wastewater being treated in anaerobic systems, including reduced use of on-site septic systems and central anaerobic treatment systems. Nitrous oxide emissions from wastewater treatment processes gradually increased across the time series as a result of increasing U.S. population and protein consumption.

2.2 Emissions by Economic Sector

Throughout this report, emission estimates are grouped into five sectors (i.e., chapters) defined by the IPCC and detailed above: Energy; Industrial Processes and Product Use; Agriculture; LULUCF; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following U.S. economic sectors: residential, commercial, industry, transportation, electricity generation, and agriculture, as well as U.S. Territories.

Using this categorization, emissions from electricity generation accounted for the largest portion (30 percent) of U.S. greenhouse gas emissions in 2014. Transportation activities, in aggregate, accounted for the second largest portion (26 percent). Emissions from industry accounted for about 21 percent of U.S. greenhouse gas emissions in 2014. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 22 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. Territories. The residential sector accounted for 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 9 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for roughly 7 percent of emissions, while U.S. Territories accounted for less than 1 percent. Carbon dioxide was also emitted and sequestered (in the form of C) by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

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 2-12 shows the trend in emissions by sector from 1990 to 2014.

Figure 2-12: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

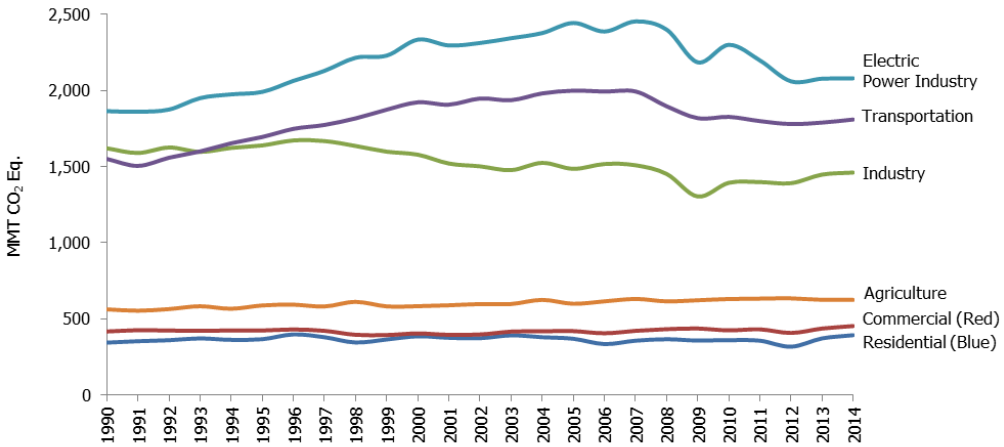


Table 2-10: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq. and Percent of Total in 2014)

Sector/Source	1990	2005	2010	2011	2012	2013	2014	Percent[a]
Electric Power Industry	**1,864.8**	**2,443.9**	**2,300.5**	**2,198.1**	**2,060.7**	**2,078.0**	**2,080.7**	**30.3%**
CO_2 from Fossil Fuel Combustion	1,820.8	2,400.9	2,258.4	2,157.7	2,022.2	2,038.1	2,039.3	29.7%
Stationary Combustion	7.7	16.5	18.9	18.0	18.2	19.5	20.0	0.3%
Incineration of Waste	8.4	12.8	11.4	10.9	10.7	9.7	9.7	0.1%
Other Process Uses of Carbonates	2.5	3.2	4.8	4.7	4.0	5.2	6.0	0.1%
Electrical Transmission and Distribution	25.4	10.6	7.0	6.8	5.6	5.4	5.6	0.1%
Transportation	**1,551.3**	**1,999.6**	**1,827.4**	**1,799.6**	**1,780.4**	**1,789.9**	**1,810.3**	**26.3%**
CO_2 from Fossil Fuel Combustion	1,493.8	1,887.0	1,728.3	1,707.6	1,696.8	1,713.0	1,737.6	25.3%
Substitution of Ozone Depleting Substances	+	67.1	65.6	60.2	55.1	49.8	47.2	0.7%
Mobile Combustion	45.7	35.3	24.0	22.7	20.2	18.3	16.3	0.2%
Non-Energy Use of Fuels	11.8	10.2	9.5	9.0	8.3	8.8	9.1	0.1%
Industry	**1,620.9**	**1,486.2**	**1,394.5**	**1,399.0**	**1,392.1**	**1,448.2**	**1,461.7**	**21.3%**
CO_2 from Fossil Fuel Combustion	811.4	780.6	727.4	723.4	731.5	761.8	762.1	11.1%
Natural Gas Systems	244.5	207.4	198.6	205.7	207.8	214.0	218.5	3.2%
Non-Energy Use of Fuels	100.6	120.6	100.8	95.8	93.5	109.1	101.6	1.5%
Petroleum Systems	42.3	52.8	58.2	60.5	62.2	68.4	71.7	1.0%
Coal Mining	96.5	64.1	82.3	71.2	66.5	64.6	67.6	1.0%
Iron and Steel Production	99.7	66.6	55.7	59.9	54.2	52.2	55.4	0.8%
Cement Production	33.3	45.9	31.3	32.0	35.1	36.1	38.8	0.6%
Petrochemical Production	21.8	27.5	27.3	26.4	26.5	26.5	26.6	0.4%
Substitution of Ozone Depleting Substances	+	7.3	15.3	17.0	18.7	20.4	22.2	0.3%
Lime Production	11.7	14.6	13.4	14.0	13.7	14.0	14.1	0.2%
Nitric Acid Production	12.1	11.3	11.5	10.9	10.5	10.7	10.9	0.2%
Ammonia Production	13.0	9.2	9.2	9.3	9.4	10.0	9.4	0.1%
Abandoned Underground Coal Mines	7.2	6.6	6.6	6.4	6.2	6.2	6.3	0.1%
Other Process Uses of Carbonates	2.5	3.2	4.8	4.7	4.0	5.2	6.0	0.1%
Adipic Acid Production	15.2	7.1	4.2	10.2	5.5	4.0	5.4	0.1%
Aluminum Production	28.3	7.6	4.6	6.8	6.4	6.2	5.4	0.1%
HCFC-22 Production	46.1	20.0	8.0	8.8	5.5	4.1	5.0	0.1%
Semiconductor Manufacture	3.6	4.7	4.0	5.1	4.5	4.2	4.7	0.1%
Carbon Dioxide Consumption	1.5	1.4	4.4	4.1	4.0	4.2	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%
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.7	4.0	4.4	4.2	4.0	0.1%
Stationary Combustion	4.9	4.6	3.9	3.9	3.9	3.9	3.9	0.1%
Soda Ash Production and Consumption	2.8	3.0	2.7	2.7	2.8	2.8	2.8	+
Ferroalloy Production	2.2	1.4	1.7	1.7	1.9	1.8	1.9	+
Titanium Dioxide Production	1.2	1.8	1.8	1.7	1.5	1.7	1.8	+
Mobile Combustion	0.9	1.3	1.4	1.4	1.4	1.5	1.5	+
Glass Production	1.5	1.9	1.5	1.3	1.2	1.3	1.3	+
Magnesium Production and Processing	5.2	2.7	2.1	2.8	1.7	1.5	1.2	+
Phosphoric Acid Production	1.5	1.3	1.1	1.2	1.1	1.1	1.1	+
Zinc Production	0.6	1.0	1.2	1.3	1.5	1.4	1.0	+
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	**563.4**	**600.2**	**631.1**	**633.7**	**635.4**	**626.3**	**625.4**	**9.1%**
N_2O from Agricultural Soil Management	303.3	297.2	320.7	323.1	323.1	318.6	318.4	4.6%
Enteric Fermentation	164.2	168.9	171.3	168.9	166.7	165.5	164.3	2.4%
Manure Management	51.1	72.9	78.1	78.9	81.2	78.9	78.7	1.1%
CO_2 from Fossil Fuel Combustion	31.0	47.4	48.2	49.9	51.4	50.4	51.2	0.7%
Rice Cultivation	13.1	13.0	11.9	11.8	11.9	11.9	11.9	0.2%

Mobile Combustion	0.3	0.5	0.5	0.5	0.6	0.6	0.6	+
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4	+
Stationary Combustion	+	+	+	+	+	+	+	+
Commercial	**418.1**	**420.3**	**425.5**	**432.1**	**408.5**	**437.5**	**453.9**	**6.6%**
CO_2 from Fossil Fuel Combustion	217.4	223.5	220.1	220.7	196.7	221.0	231.9	3.4%
Landfills	179.6	154.0	142.1	144.4	142.3	144.3	148.0	2.2%
Substitution of Ozone Depleting Substances	+	17.6	38.5	42.1	44.9	47.4	49.2	0.7%
Wastewater Treatment	15.7	15.9	15.5	15.3	15.0	14.8	14.7	0.2%
Human Sewage	3.4	4.3	4.5	4.7	4.8	4.8	4.8	0.1%
Composting	0.7	3.5	3.5	3.5	3.7	3.9	3.9	0.1%
Stationary Combustion	1.4	1.4	1.4	1.4	1.2	1.3	1.4	+
Residential	**344.9**	**370.4**	**361.2**	**357.6**	**318.4**	**372.6**	**393.7**	**5.7%**
CO_2 from Fossil Fuel Combustion	338.3	357.8	334.6	326.8	282.5	329.7	345.1	5.0%
Substitution of Ozone Depleting Substances	0.3	7.7	21.8	25.9	31.4	37.0	42.6	0.6%
Stationary Combustion	6.3	4.9	4.8	4.9	4.5	5.9	6.0	0.1%
U.S. Territories	**33.7**	**58.2**	**45.3**	**45.4**	**47.6**	**47.5**	**44.7**	**0.7%**
CO_2 from Fossil Fuel Combustion	27.9	49.9	41.4	41.5	43.6	43.5	41.0	0.6%
Non-Energy Use of Fuels	5.7	8.1	3.7	3.7	3.8	3.8	3.5	0.1%
Stationary Combustion	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
Total Emissions	**6,397.1**	**7,378.8**	**6,985.5**	**6,865.4**	**6,643.0**	**6,800.0**	**6,870.5**	**100.0%**
LULUCF Sector Total[b]	**(738.0)**	**(698.5)**	**(766.4)**	**(762.0)**	**(749.7)**	**(759.6)**	**(762.5)**	**(11.1%)**
Net Emissions (Sources and Sinks)	**5,659.2**	**6,680.3**	**6,219.0**	**6,103.4**	**5,893.3**	**6,040.4**	**6,108.0**	**88.9%**

Note: 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 2014.
[b] The LULUCF Sector Total is the net sum of all emissions (i.e., sources) of greenhouse gases to the atmosphere plus removals of CO_2 (i.e., sinks or negative emissions) from the atmosphere.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 30 percent of total U.S. greenhouse gas emissions in 2014. Emissions increased by 12 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions increased from 2013 to 2014 by 0.1 percent, primarily due to increased CO_2 emissions from fossil fuel combustion. Electricity sales to the residential and commercial end-use sectors in 2014 increased approximately 0.9 percent and 1.1 percent, respectively. The trend in the residential and commercial sectors can largely be attributed to colder more energy-intensive winter conditions compared to 2013. Electricity sales to the industrial sector in 2014 increased by approximately 1.2 percent. Overall, in 2014, the amount of electricity generated (in kWh) increased by 1.1 percent from the previous year. Despite this increase in generation, CO_2 emissions from the electric power sector increased by 0.1 percent as the consumption of petroleum for electricity generation increased by 15.8 percent in 2014 and the consumption of CO_2-intensive coal and natural gas for electricity generation decreased by 0.1 and 0.2 percent, respectively. Table 2-11 provides a detailed summary of emissions from electricity generation-related activities.

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

Gas/Fuel Type or Source	1990	2005	2010	2011	2012	2013	2014
CO_2	**1,831.2**	**2,416.5**	**2,274.2**	**2,172.9**	**2,036.6**	**2,052.8**	**2,054.8**
Fossil Fuel Combustion	1,820.8	2,400.9	2,258.4	2,157.7	2,022.2	2,038.1	2,039.3
Coal	*1,547.6*	*1,983.8*	*1,827.6*	*1,722.7*	*1,511.2*	*1,571.3*	*1,570.4*
Natural Gas	*175.3*	*318.8*	*399.0*	*408.8*	*492.2*	*444.0*	*443.2*

Petroleum	*97.5*	*97.9*	*31.4*	*25.8*	*18.3*	*22.4*	*25.3*
Geothermal	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0	12.5	11.0	10.5	10.4	9.4	9.4
Other Process Uses of Carbonates	2.5	3.2	4.8	4.7	4.0	5.2	6.0
CH_4	**0.3**	**0.5**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**
Stationary Sources (Elec Gen)	0.3	0.5	0.5	0.4	0.4	0.4	0.4
Incineration of Waste	+	+	+	+	+	+	+
N_2O	**7.8**	**16.4**	**18.8**	**17.9**	**18.1**	**19.4**	**19.9**
Stationary Sources (Elec Gen)	7.4	16.0	18.5	17.6	17.8	19.1	19.6
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
SF_6	**25.4**	**10.6**	**7.0**	**6.8**	**5.6**	**5.4**	**5.6**
Electrical Transmission and Distribution	25.4	10.6	7.0	6.8	5.6	5.4	5.6
Total	**1,864.8**	**2,443.9**	**2,300.5**	**2,198.1**	**2,060.7**	**2,078.0**	**2,080.7**

+ Does not exceed 0.05 MMT CO_2 Eq.

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

Note: Totals may not sum due to independent rounding.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to each economic sector's share of retail sales of electricity consumption (EIA 2016 and Duffield 2006). These source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Incineration of Waste, Other Process Uses of Carbonates, and SF_6 from Electrical Transmission and Distribution Systems. Note that only 50 percent of the Other Process Uses of Carbonates emissions were associated with electricity generation and distributed as described; the remainder of Other Process Uses of Carbonates emissions were attributed to the industrial processes economic end-use sector.[6]

When emissions from electricity are distributed among these sectors, industrial activities account for the largest share of total U.S. greenhouse gas emissions (29.2 percent), followed closely by emissions from transportation (26.4 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 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-12 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-13 shows the trend in these emissions by sector from 1990 to 2014.

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

Figure 2-13: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO_2 Eq.)

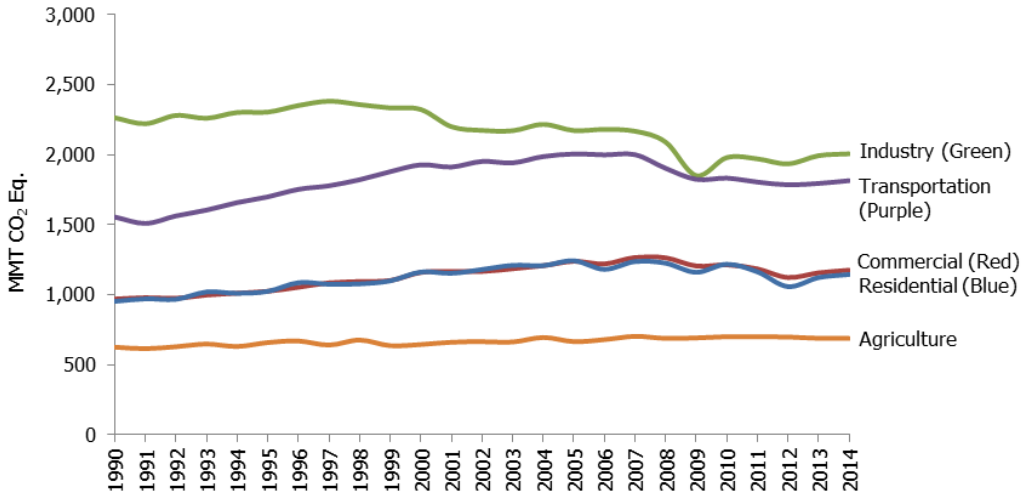


Table 2-12: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (MMT CO_2 Eq.) and Percent of Total in 2014

Sector/Gas	1990	2005	2010	2011	2012	2013	2014	Percent[a]
Industry	**2,262.9**	**2,171.9**	**1,979.1**	**1,970.0**	**1,934.0**	**1,992.5**	**2,005.7**	**29.2%**
Direct Emissions	**1,620.9**	**1,486.2**	**1,394.5**	**1,399.0**	**1,392.1**	**1,448.2**	**1,461.7**	**21.3%**
CO_2	1,157.9	1,122.3	1,028.8	1,027.2	1,029.5	1,079.6	1,081.7	15.7%
CH_4	351.4	298.9	310.9	305.8	305.5	312.9	320.0	4.7%
N_2O	35.4	26.7	23.7	29.1	24.0	22.7	24.5	0.4%
HFCs, PFCs, SF_6, and NF_3	76.3	38.2	31.1	36.9	33.1	33.0	35.5	0.5%
Electricity-Related	**642.0**	**685.7**	**584.5**	**571.0**	**541.9**	**544.3**	**544.0**	**7.9%**
CO_2	630.4	678.0	577.9	564.4	535.6	537.7	537.2	7.8%
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+
N_2O	2.7	4.6	4.8	4.7	4.8	5.1	5.2	0.1%
SF_6	8.7	3.0	1.8	1.8	1.5	1.4	1.5	+
Transportation	**1,554.4**	**2,004.4**	**1,832.0**	**1,803.9**	**1,784.3**	**1,794.0**	**1,814.5**	**26.4%**
Direct Emissions	**1,551.3**	**1,999.6**	**1,827.4**	**1,799.6**	**1,780.4**	**1,789.9**	**1,810.3**	**26.3%**
CO_2	1,505.6	1,897.2	1,737.8	1,716.6	1,705.0	1,721.8	1,746.7	25.4%
CH_4	5.4	2.4	1.9	1.8	1.8	1.7	1.6	+
N_2O	40.3	32.9	22.1	20.9	18.5	16.6	14.7	0.2%
HFCs[b]	+	67.1	65.6	60.2	55.1	49.8	47.2	0.7%
Electricity-Related	**3.1**	**4.8**	**4.6**	**4.3**	**3.9**	**4.1**	**4.1**	**0.1%**
CO_2	3.1	4.8	4.5	4.3	3.9	4.0	4.1	0.1%
CH_4	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+
Commercial	**969.1**	**1,238.0**	**1,212.8**	**1,183.9**	**1,122.1**	**1,155.8**	**1,174.7**	**17.1%**
Direct Emissions	**418.1**	**420.3**	**425.5**	**432.1**	**408.5**	**437.5**	**453.9**	**6.6%**
CO_2	217.4	223.5	220.1	220.7	196.7	221.0	231.9	3.4%
CH_4	196.6	172.8	160.5	162.5	160.1	162.2	165.8	2.4%
N_2O	4.1	6.4	6.4	6.7	6.7	6.9	7.0	0.1%
HFCs	+	17.6	38.5	42.1	44.9	47.4	49.2	0.7%
Electricity-Related	**551.0**	**817.7**	**787.3**	**751.9**	**713.6**	**718.3**	**720.8**	**10.5%**
CO_2	541.1	808.5	778.3	743.3	705.2	709.5	711.8	10.4%
CH_4	0.1	0.2	0.2	0.2	0.1	0.2	0.2	+
N_2O	2.3	5.5	6.4	6.1	6.3	6.7	6.9	0.1%

SF_6	7.5	3.5	2.4	2.3	1.9	1.9	1.9	+
Residential	**952.2**	**1,242.1**	**1,216.9**	**1,163.1**	**1,057.5**	**1,121.9**	**1,143.8**	**16.6%**
Direct Emissions	**344.9**	**370.4**	**361.2**	**357.6**	**318.4**	**372.6**	**393.7**	**5.7%**
CO_2	338.3	357.8	334.6	326.8	282.5	329.7	345.1	5.0%
CH_4	5.2	4.1	4.0	4.0	3.7	5.0	5.0	0.1%
N_2O	1.0	0.9	0.8	0.8	0.7	1.0	1.0	+
HFCs	0.3	7.7	21.8	25.9	31.4	37.0	42.6	0.6%
Electricity-Related	**607.3**	**871.7**	**855.7**	**805.5**	**739.1**	**749.3**	**750.2**	**10.9%**
CO_2	596.4	861.9	845.9	796.3	730.4	740.2	740.8	10.8%
CH_4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.5	5.8	7.0	6.6	6.5	7.0	7.2	0.1%
SF_6	8.3	3.8	2.6	2.5	2.0	1.9	2.0	+
Agriculture	**624.8**	**664.2**	**699.5**	**699.1**	**697.5**	**688.3**	**687.0**	**10.0%**
Direct Emissions	**563.4**	**600.2**	**631.1**	**633.7**	**635.4**	**626.3**	**625.4**	**9.1%**
CO_2	31.0	47.4	48.2	49.9	51.4	50.4	51.2	0.7%
CH_4	214.8	238.6	244.6	242.7	242.8	239.2	237.9	3.5%
N_2O	317.6	314.1	338.3	341.0	341.1	336.6	336.4	4.9%
Electricity-Related	**61.3**	**64.1**	**68.4**	**65.4**	**62.1**	**62.1**	**61.6**	**0.9%**
CO_2	60.2	63.4	67.6	64.7	61.4	61.3	60.8	0.9%
CH_4	+	+	+	+	+	+	+	+
N_2O	0.3	0.4	0.6	0.5	0.5	0.6	0.6	+
SF_6	0.8	0.3	0.2	0.2	0.2	0.2	0.2	+
U.S. Territories	**33.7**	**58.2**	**45.3**	**45.4**	**47.6**	**47.5**	**44.7**	**0.7%**
Total Emissions	**6,397.1**	**7,378.8**	**6,985.5**	**6,865.4**	**6,643.0**	**6,800.0**	**6,870.5**	**100.0%**
LULUCF Sector Total[c]	**(738.0)**	**(698.5)**	**(766.4)**	**(762.0)**	**(749.7)**	**(759.6)**	**(762.5)**	**(11.1%)**
Net Emissions (Sources and Sinks)	**5,659.2**	**6,680.3**	**6,219.0**	**6,103.4**	**5,893.3**	**6,040.4**	**6,108.0**	**88.9%**

Note: Total emissions presented without LULUCF. 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 year 2014.

[b] Includes primarily HFC-134a.

[c] The LULUCF Sector Total is the net sum of all emissions (i.e., sources) of greenhouse gases to the atmosphere plus removals of CO_2 (i.e., sinks or negative emissions) from the atmosphere.

Notes: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector. Totals may not sum due to independent rounding.

Industry

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

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 26 percent of U.S. greenhouse gas emissions in 2014. The largest sources of transportation greenhouse gases in 2014 were passenger cars (42.0 percent), freight trucks (22.5 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18.6 percent), commercial aircraft (6.4 percent), rail (2.6 percent), pipelines

(2.6 percent), and ships and boats (1.6 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 2014, total transportation emissions rose by 17 percent due, in large part, to increased demand for travel as fleet wide light-duty vehicle fuel economy was relatively stable (average new vehicle fuel economy declined slowly from 1990 through 2004 and then increased more rapidly from 2005 through 2014). The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased 37 percent from 1990 to 2014, 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, the rate of VMT growth slowed while average new vehicle fuel economy began to increase. Average new vehicle fuel economy has improved almost every year since 2005, and the truck share has decreased to about 41 percent of new vehicles in Model Year (MY) 2014 (EPA 2015a). Between 2013 and 2014, VMT increased by only 1.3 percent. Table 2-13 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals.

From 2008 to 2009, CO_2 emissions from the transportation end-use sector declined 4.2 percent. The decrease in emissions could largely be attributed to decreased economic activity in 2009 and an associated decline in the demand for transportation. Modes such as medium- and heavy-duty trucks were significantly impacted by the decline in freight transport. After reaching a decadal low in 2012, CO_2 emissions from the transportation end-use sector stabilized and grew slowly in 2013 and 2014 as the economic recovery gained strength.

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder. The primary driver of transportation-related emissions was CO_2 from fossil fuel combustion, which increased by 16 percent from 1990 to 2014. This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 47.2 MMT CO_2 Eq. in 2014, led to an increase in overall emissions from transportation activities of 17 percent.

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

Gas/Vehicle	1990	2005	2010	2011	2012	2013	2014
Passenger Cars	**656.6**	**708.9**	**783.6**	**774.3**	**767.9**	**763.2**	**762.5**
CO_2	629.3	660.1	742.0	736.9	735.5	735.5	737.6
CH_4	3.2	1.2	1.2	1.2	1.1	1.0	1.0
N_2O	24.1	15.9	12.9	12.3	10.7	9.4	8.0
HFCs	+	31.7	27.5	23.9	20.6	17.3	16.0
Light-Duty Trucks	**335.6**	**551.5**	**348.9**	**332.0**	**326.0**	**323.4**	**338.1**
CO_2	321.1	504.3	308.8	294.8	291.9	292.5	309.2
CH_4	1.7	0.8	0.4	0.4	0.3	0.3	0.3
N_2O	12.8	13.2	5.5	5.0	4.4	3.9	3.6
HFCs	+	33.3	34.2	31.7	29.3	26.7	25.0
Medium- and Heavy-Duty Trucks	**231.1**	**398.2**	**389.7**	**388.4**	**388.7**	**395.7**	**407.4**
CO_2	230.1	395.4	385.6	383.9	383.7	390.3	402.0
CH_4	0.3	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.7	1.1	1.1	1.0	0.9	0.9	0.9
HFCs	+	1.5	2.9	3.4	3.9	4.4	4.4
Buses	**8.4**	**12.1**	**15.8**	**16.8**	**17.8**	**18.0**	**19.1**
CO_2	8.4	11.8	15.3	16.2	17.3	17.5	18.6
CH_4	+	+	+	+	+	+	+
N_2O	+	+	0.1	0.1	0.1	0.1	0.1
HFCs	+	0.3	0.4	0.4	0.4	0.4	0.4
Motorcycles	**1.8**	**1.7**	**3.7**	**3.6**	**4.2**	**4.0**	**3.9**
CO_2	1.7	1.6	3.6	3.6	4.1	3.9	3.8

CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
Commercial Aircraft[a]	**110.9**	**134.0**	**114.4**	**115.7**	**114.3**	**115.4**	**116.3**
CO_2	109.9	132.7	113.3	114.6	113.3	114.3	115.2
CH_4	+	+	+	+	+	+	+
N_2O	1.0	1.2	1.0	1.1	1.0	1.1	1.1
Other Aircraft[b]	**78.3**	**59.7**	**40.4**	**34.2**	**32.1**	**34.7**	**35.2**
CO_2	77.5	59.1	40.1	33.9	31.8	34.4	34.9
CH_4	0.1	0.1	+	+	+	+	+
N_2O	0.7	0.5	0.4	0.3	0.3	0.3	0.3
Ships and Boats[c]	**44.9**	**44.9**	**44.7**	**46.4**	**40.1**	**39.4**	**28.6**
CO_2	44.3	44.3	44.0	45.5	39.3	38.7	28.0
CH_4	+	+	+	+	+	+	+
N_2O	0.6	0.6	0.8	0.8	0.7	0.7	0.5
HFCs	+	+	+	+	+	+	+
Rail	**39.0**	**51.1**	**44.2**	**45.9**	**44.6**	**45.5**	**47.6**
CO_2	38.5	50.3	43.1	44.7	43.4	44.2	45.7
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	0.4
HFCs	+	0.3	0.6	0.7	0.8	0.9	1.4
Other Emissions from Electricity Generation[d]	0.1	0.1	+	+	+	+	+
Pipelines[e]	**36.0**	**32.2**	**37.1**	**37.8**	**40.3**	**45.9**	**46.5**
CO_2	36.0	32.2	37.1	37.8	40.3	45.9	46.5
Lubricants	**11.8**	**10.2**	**9.5**	**9.0**	**8.3**	**8.8**	**9.1**
CO_2	11.8	10.2	9.5	9.0	8.3	8.8	9.1
Total Transportation	**1,554.4**	**2,004.4**	**1,832.0**	**1,803.9**	**1,784.3**	**1,794.0**	**1,814.5**
International Bunker	*104.5*	*114.2*	*118.1*	*112.8*	*106.8*	*100.7*	*104.2*

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

[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 U.S. Inventory.

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

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

Commercial

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

Residential

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

Agriculture

The agriculture end-use sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2014, agricultural soil management was the largest source of N_2O emissions, and enteric fermentation was the second largest source of CH_4 emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment like tractors. The agriculture sector is less reliant on electricity than the other sectors.

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

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

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

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

For the Industry economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA industrial fuel consuming sector, minus the agricultural use of fuel explained below, are apportioned to this economic sector. The CH_4 and N_2O emissions from stationary and mobile combustion are also apportioned to this economic sector based on the EIA industrial fuel consuming sector, minus emissions apportioned to the Agriculture economic sector described below. Substitution of Ozone Depleting Substance emissions are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector. Additionally, all process-related emissions from sources with methods considered within the IPCC IPPU sector have been apportioned to this economic sector. This includes the process-related emissions (i.e., emissions from the actual process to make the material, not from fuels to power the plant) from such activities as Cement Production, Iron and Steel Production and Metallurgical Coke Production, and Ammonia Production. Additionally, fugitive emissions from energy production sources, such as Natural Gas Systems, Coal Mining, and Petroleum Systems are included in the Industry economic sector. A portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in large industrial facilities) are also included in the Industry economic sector. Finally,

all remaining CO_2 emissions from Non-Energy Uses of Fossil Fuels are assumed to be industrial in nature (besides the lubricants for transportation vehicles specified above), and are attributed to the Industry economic sector.

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

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

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

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

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2014; (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. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.3 percent since 1990. Since 1990, this rate is slightly slower than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product and national population (see Table 2-14 and Figure 2-14).

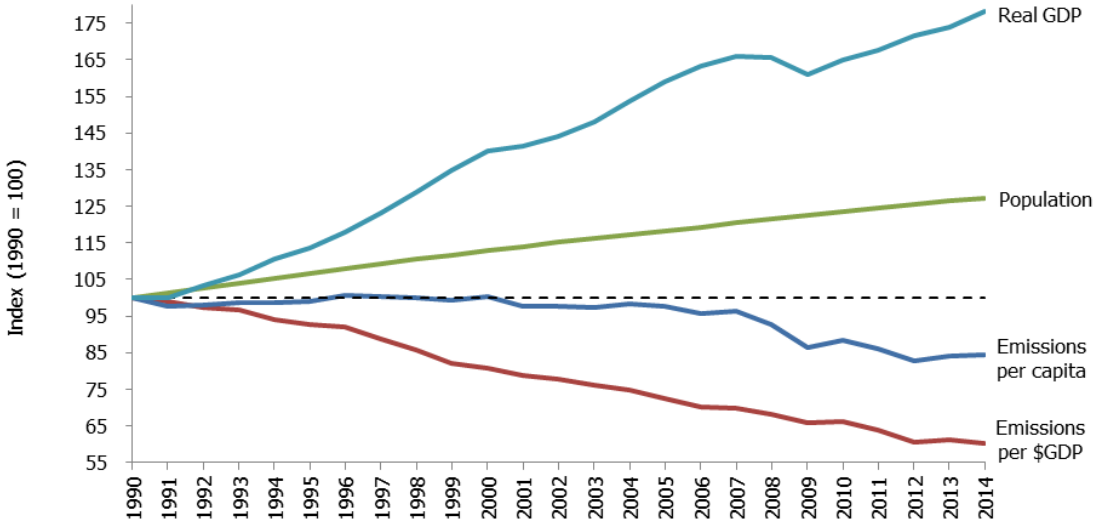
Table 2-14: Recent Trends in Various U.S. Data (Index 1990 = 100)

Chapter/IPCC Sector	1990	2005	2010	2011	2012	2013	2014	Growth[a]
Greenhouse Gas Emissions[b]	100	115	109	107	104	106	107	0.3%
Energy Consumption[c]	100	118	116	115	112	116	117	0.7%
Fossil Fuel Consumption[c]	100	119	112	110	107	110	111	0.5%
Electricity Consumption[c]	100	134	137	137	135	136	138	1.4%
GDP[d]	100	159	165	168	171	174	178	2.5%
Population[e]	100	118	124	125	126	126	127	1.0%

[a] Average annual growth rate

[b] GWP-weighted values
[c] Energy-content-weighted values (EIA 2016)
[d] Gross Domestic Product in chained 2009 dollars (BEA 2016)
[e] U.S. Census Bureau (2015)

Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product



Source: BEA (2016), U.S. Census Bureau (2015), 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[7] 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.

[7] See <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2>.

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 CO's interaction with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2015),[8] 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	2010	2011	2012	2013	2014
NO_x	**21,783**	**17,421**	**12,565**	**12,416**	**11,778**	**11,195**	**10,633**
Mobile Fossil Fuel Combustion	10,862	10,295	7,290	7,294	6,788	6,283	5,777
Stationary Fossil Fuel Combustion	10,023	5,858	4,092	3,807	3,567	3,579	3,522
Oil and Gas Activities	139	321	545	622	622	622	622
Industrial Processes and Product Use	592	572	472	452	452	452	452
Forest Fires	78	239	80	159	266	177	177
Waste Combustion	82	128	77	73	73	73	73
Agricultural Burning	6	6	7	8	8	8	8
Waste	+	2	1	1	1	1	1
CO	**132,764**	**75,240**	**49,507**	**51,238**	**53,240**	**48,229**	**46,413**
Mobile Fossil Fuel Combustion	119,360	58,615	39,475	38,305	36,491	34,676	32,861
Forest Fires	2,792	8,515	2,845	5,683	9,499	6,298	6,298
Stationary Fossil Fuel Combustion	5,000	4,648	4,103	4,170	4,170	4,170	4,169
Industrial Processes and Product Use	4,129	1,557	1,280	1,229	1,229	1,229	1,229
Waste Combustion	978	1,403	1,084	1,003	1,003	1,003	1,003
Oil and Gas Activities	302	318	487	610	610	610	610
Agricultural Burning	202	177	229	233	234	238	238
Waste	1	7	5	5	5	5	5
NMVOCs	**20,930**	**13,154**	**11,641**	**11,726**	**11,416**	**11,107**	**10,796**
Industrial Processes and Product Use	7,638	5,849	4,133	3,929	3,929	3,929	3,928
Mobile Fossil Fuel Combustion	10,932	5,724	4,591	4,562	4,252	3,942	3,632
Oil and Gas Activities	554	510	2,205	2,517	2,517	2,517	2,517
Stationary Fossil Fuel Combustion	912	716	576	599	599	599	599
Waste Combustion	222	241	92	81	81	81	81
Waste	673	114	44	38	38	38	39
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**7,014**	**5,877**	**4,711**	**4,625**	**4,528**
Stationary Fossil Fuel Combustion	18,407	11,541	6,120	5,008	3,859	3,790	3,710
Industrial Processes and Product Use	1,307	831	617	604	604	604	604
Mobile Fossil Fuel Combustion	390	180	117	108	108	108	108
Oil and Gas Activities	793	619	144	142	125	108	90
Waste Combustion	38	25	16	15	15	15	15
Waste	+	1	+	+	+	+	+
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

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

[8] NO_x and CO emission estimates from Field Burning of Agricultural Residues were estimated separately, and therefore not taken from EPA (2015).

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 2001). However, because SO_2 is short-lived and unevenly distributed in the atmosphere, its radiative forcing impacts are highly uncertain.

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

Electricity generation is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 64.0 percent in 2014. 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.