2. Trends in Greenhouse Gas Emissions

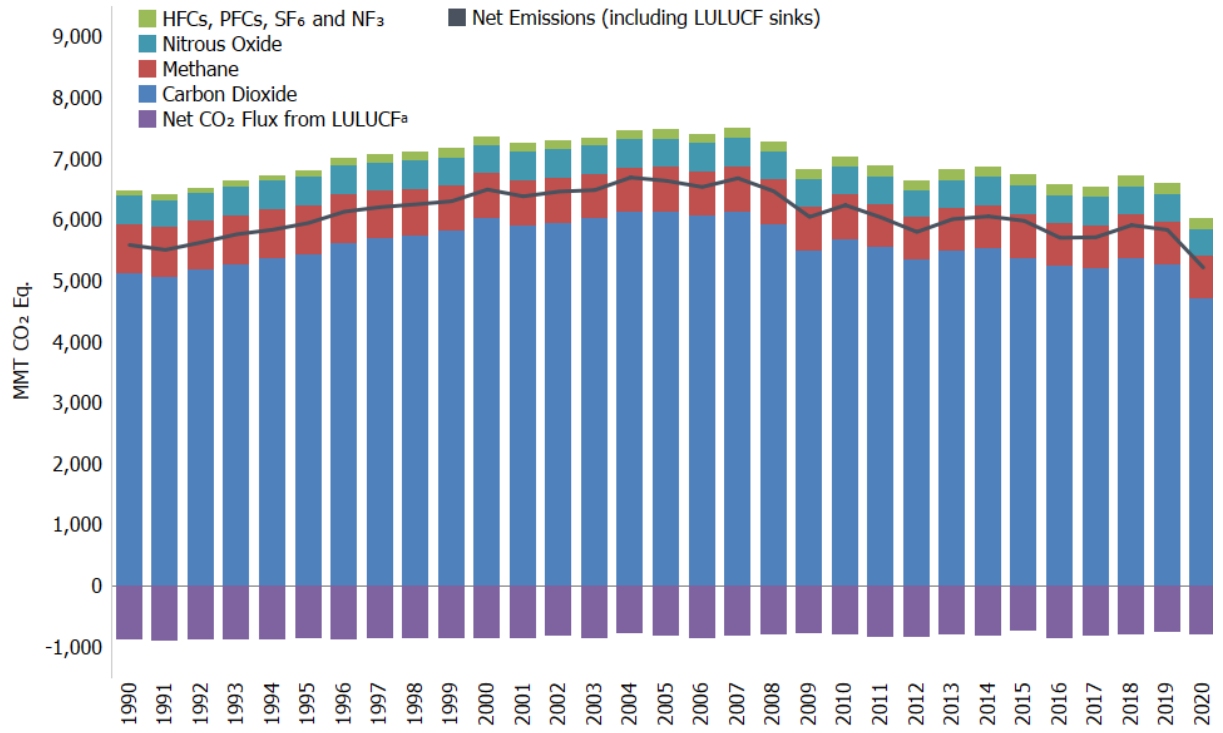
2.1 Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2020, total gross U.S. greenhouse gas emissions were 5,981.4 million metric tons carbon dioxide equivalent (MMT CO_2 Eq).[1] Total U.S. emissions have decreased by 7.3 percent from 1990 to 2020, down from a high of 15.7 percent above 1990 levels in 2007. Emissions decreased from 2019 to 2020 by 9.0 percent (590.4 MMT CO_2 Eq.). Net emissions (i.e., including sinks) were 5,222.4 MMT CO_2 Eq. in 2020. Overall, net emissions decreased 10.6 percent from 2019 to 2020 and decreased 21.4 percent from 2005 levels, as shown in Table 2-1. The sharp decline in emissions from 2019 to 2020 is largely due to the impacts of the coronavirus (COVID-19) pandemic on travel and economic activity; however, the decline also reflects the combined impacts of long-term trends in many factors, including population, economic growth, energy markets, technological changes including energy efficiency, and the carbon intensity of energy fuel choices. Between 2019 and 2020, the decrease in total greenhouse gas emissions was driven largely by a 10.5 percent decrease in CO_2 emissions from fossil fuel combustion, including a 13.3 percent decrease in transportation sector emissions from less travel due to the COVID-19 pandemic and a 10.4 percent decrease in the electric power sector. The decrease in electric power sector emissions was due to a decrease in electricity demand of 2.5 percent since 2019 and also reflects the continued shift from coal to less carbon intensive natural gas and renewables.

Figure 2-1 and Figure 2-2 illustrate the overall trend in total U.S. emissions and sinks by gas, annual changes, and relative changes since 1990.

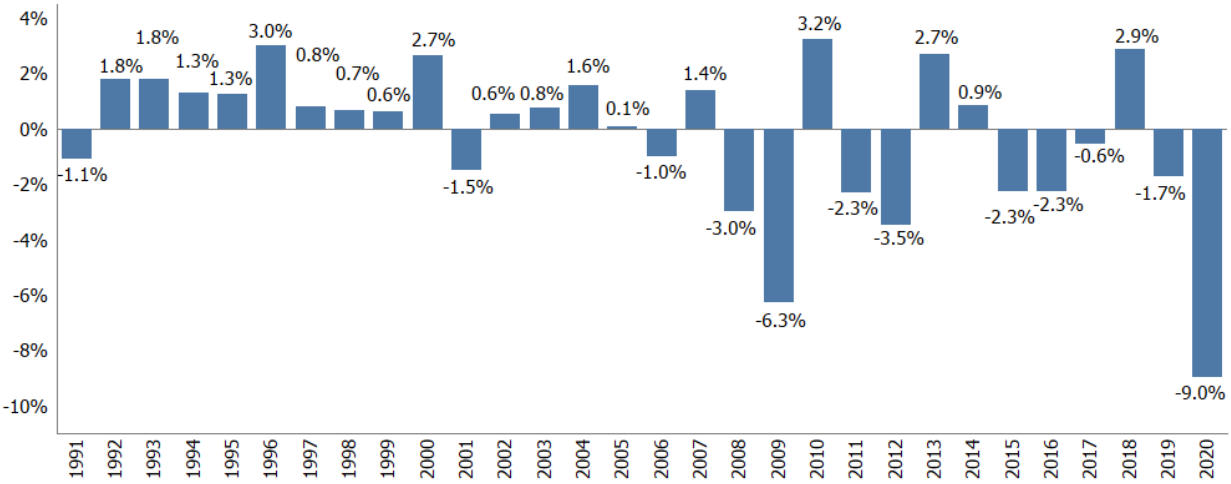
[1] The gross emissions total presented in this report for the United States excludes emissions and sinks from removals from Land Use, Land-Use Change, and Forestry (LULUCF). The net emissions total presented in this report for the United States includes emissions and sinks from removals from LULUCF.

Figure 2-1: U.S. Greenhouse Gas Emissions and Sinks by Gas



[a] The term "flux" is used to describe the exchange of CO_2 to and from the atmosphere, with net flux being either positive or negative depending on the overall balance. Removal and long-term storage of CO_2 from the atmosphere is also referred to as "carbon sequestration."

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



Overall from 1990 to 2020, total emissions of CO_2 decreased by 406.8 MMT CO_2 Eq. (7.9 percent), as total emissions of methane (CH_4) decreased by 130.4 MMT CO_2 Eq. (16.7 percent), and total emissions of nitrous oxide (N_2O) decreased by 24.4 MMT CO_2 Eq. (5.4 percent). During the same period, emissions of fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) rose by 89.5 MMT CO_2 Eq. (89.8 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, SF_6, and NF_3 are significant because many of them have

extremely high global warming potentials (GWPs), and, in the cases of PFCs, SF_6, and NF_3, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon (C) sequestration in managed forests, trees in urban areas, agricultural soils, landfilled yard trimmings, and coastal wetlands. These were estimated to offset 13.6 percent (812.2 MMT CO_2 Eq.) of total emissions in 2020.

Table 2-1 provides information on trends in 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	2016	2017	2018	2019	2020
CO_2	**5,122.5**	**6,137.6**	**5,251.8**	**5,211.0**	**5,376.7**	**5,259.1**	**4,715.7**
Fossil Fuel Combustion	4,731.2	5,752.0	4,909.6	4,853.3	4,989.3	4,852.3	4,342.7
Transportation	*1,468.9*	*1,858.6*	*1,757.6*	*1,780.0*	*1,812.8*	*1,813.8*	*1,572.0*
Electric Power Sector	*1,820.0*	*2,400.1*	*1,808.9*	*1,732.0*	*1,752.9*	*1,606.1*	*1,439.0*
Industrial	*853.7*	*851.5*	*792.7*	*790.4*	*814.1*	*816.1*	*766.3*
Residential	*338.6*	*358.9*	*292.8*	*293.4*	*338.2*	*341.4*	*315.8*
Commercial	*228.3*	*227.1*	*231.5*	*232.0*	*245.8*	*250.7*	*226.8*
U.S. Territories	*21.7*	*55.9*	*26.0*	*25.5*	*25.5*	*24.3*	*22.7*
Non-Energy Use of Fuels	112.2	128.9	99.5	112.6	128.9	126.8	121.0
Cement Production	33.5	46.2	39.4	40.3	39.0	40.9	40.7
Iron and Steel Production & Metallurgical Coke Production	104.7	70.1	43.6	40.6	42.6	43.1	37.7
Natural Gas Systems	31.9	24.9	29.8	31.1	32.4	38.7	35.4
Petroleum Systems	9.6	12.0	21.9	25.0	37.3	46.7	30.2
Petrochemical Production	21.6	27.4	28.1	28.9	29.3	30.7	30.0
Incineration of Waste	12.9	13.3	14.4	13.2	13.3	12.9	13.1
Ammonia Production	13.0	9.2	10.2	11.1	12.2	12.3	12.7
Lime Production	11.7	14.6	12.6	12.9	13.1	12.1	11.3
Other Process Uses of Carbonates	6.2	7.5	10.8	9.9	7.4	9.8	9.8
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	5.3	5.2	6.0	6.0	6.0
Urea Fertilization	2.4	3.5	4.7	4.9	5.0	5.1	5.3
Carbon Dioxide Consumption	1.5	1.4	4.6	4.6	4.1	4.9	5.0
Liming	4.7	4.3	3.1	3.1	2.2	2.4	2.4
Coal Mining	4.6	4.2	2.8	3.1	3.1	3.0	2.2
Glass Production	2.3	2.4	2.1	2.0	2.0	1.9	1.9
Aluminum Production	6.8	4.1	1.3	1.2	1.5	1.9	1.7
Soda Ash Production	1.4	1.7	1.7	1.8	1.7	1.8	1.5
Ferroalloy Production	2.2	1.4	1.8	2.0	2.1	1.6	1.4
Titanium Dioxide Production	1.2	1.8	1.7	1.7	1.5	1.5	1.3
Zinc Production	0.6	1.0	0.8	0.9	1.0	1.0	1.0
Phosphoric Acid Production	1.5	1.3	1.0	1.0	0.9	0.9	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Carbide Production and Consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Magnesium Production and Processing	0.1	+	+	+	+	+	+
Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*219.4*	*230.7*	*316.9*	*312.7*	*319.8*	*317.2*	*291.6*
International Bunker Fuels[b]	*103.6*	*113.3*	*116.7*	*120.2*	*122.2*	*116.1*	*69.6*
CH_4[c]	**780.8**	**697.5**	**657.6**	**663.8**	**671.1**	**668.8**	**650.4**
Enteric Fermentation	163.5	168.0	171.3	174.9	175.7	176.1	175.2
Natural Gas Systems	195.5	177.5	165.2	166.6	171.8	172.1	164.9
Landfills	176.6	131.5	107.9	109.2	111.7	113.6	109.3

Manure Management	34.8	49.0	57.1	57.5	59.4	58.7	59.6
Coal Mining	96.5	64.1	53.8	54.8	52.7	47.4	41.2
Petroleum Systems	47.8	41.4	40.4	40.5	38.6	40.4	40.2
Wastewater Treatment	20.3	20.1	18.7	18.5	18.3	18.1	18.3
Rice Cultivation	16.0	18.0	15.8	14.9	15.6	15.1	15.7
Stationary Combustion	8.6	7.8	7.9	7.7	8.6	8.8	7.9
Abandoned Oil and Gas Wells	6.5	6.8	6.9	6.9	6.9	7.0	6.9
Abandoned Underground Coal Mines	7.2	6.6	6.7	6.4	6.2	5.9	5.8
Composting	0.4	1.9	2.3	2.5	2.3	2.3	2.3
Mobile Combustion	6.5	4.0	2.6	2.6	2.5	2.5	2.2
Field Burning of Agricultural Residues	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Petrochemical Production	0.2	0.1	0.2	0.3	0.3	0.3	0.3
Anaerobic Digestion at Biogas Facilities	+	+	0.2	0.2	0.2	0.2	0.2
Carbide Production and Consumption	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O[c]	**450.5**	**453.3**	**449.2**	**444.6**	**457.7**	**456.8**	**426.1**
Agricultural Soil Management	316.0	313.8	330.8	328.3	338.9	345.3	316.2
Wastewater Treatment	16.6	20.3	22.8	23.2	23.5	23.4	23.5
Stationary Combustion	25.1	34.4	30.0	28.4	28.2	24.9	23.2
Manure Management	13.9	16.3	18.4	19.0	19.3	19.5	19.7
Mobile Combustion	44.6	41.4	21.1	20.1	19.2	20.0	17.4
Nitric Acid Production	12.1	11.3	10.1	9.3	9.6	10.0	9.3
Adipic Acid Production	15.2	7.1	7.1	7.5	10.5	5.3	8.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	2.0	2.2	2.0	2.0	2.0
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	1.7	1.5	1.4	1.4	1.2
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Electronics Industry	+	0.1	0.2	0.3	0.3	0.2	0.3
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum Systems	+	+	+	+	+	+	+
Natural Gas Systems	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.9*	*1.0*	*1.0*	*1.1*	*1.1*	*1.0*	*0.6*
HFCs	**46.5**	**127.4**	**168.3**	**171.1**	**171.0**	**175.9**	**178.8**
Substitution of Ozone Depleting Substances[d]	0.2	107.2	165.1	165.5	167.3	171.8	176.2
HCFC-22 Production	46.1	20.0	2.8	5.2	3.3	3.7	2.1
Electronics Industry	0.2	0.2	0.3	0.4	0.4	0.4	0.4
Magnesium Production and Processing	NO	NO	0.1	0.1	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**4.4**	**4.2**	**4.8**	**4.6**	**4.4**
Electronics Industry	2.8	3.3	3.0	3.0	3.1	2.8	2.7
Aluminum Production	21.5	3.4	1.4	1.1	1.6	1.8	1.7
Substitution of Ozone Depleting Substances[d]	NO	+	+	+	0.1	0.1	0.1
Electrical Transmission and Distribution	NO	+	+	+	NO	+	+

SF_6	**28.8**	**11.8**	**6.0**	**5.9**	**5.7**	**5.9**	**5.4**
Electrical Transmission and Distribution	23.2	8.3	4.1	4.2	3.8	4.2	3.8
Magnesium Production and Processing	5.2	2.7	1.1	1.0	1.0	0.9	0.9
Electronics Industry	0.5	0.7	0.8	0.7	0.8	0.8	0.7
NF_3	**+**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Electronics Industry	+	0.5	0.6	0.6	0.6	0.6	0.6
Total Gross Emissions (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**
LULUCF Emissions[c]	**31.4**	**41.3**	**35.4**	**45.5**	**39.8**	**30.3**	**53.2**
CH_4	27.2	30.9	28.3	34.0	30.7	25.5	38.1
N_2O	4.2	10.5	7.1	11.5	9.1	4.8	15.2
LULUCF Carbon Stock Change[e]	**(892.0)**	**(831.1)**	**(862.0)**	**(826.7)**	**(809.0)**	**(760.8)**	**(812.2)**
LULUCF Sector Net Total[f]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

+ Does not exceed 0.05 MMT CO_2 Eq.

NO (Not Occurring)

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

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

[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals. LULUCF emissions include the CH_4 and N_2O emissions reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands*, Flooded Land Remaining Flooded Land, and Land Converted to Flooded Land; and N_2O emissions from Forest Soils and Settlement Soils. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

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

[e] LULUCF Carbon Stock Change is the net C stock change from the following categories: *Forest Land Remaining Forest Land*, *Land Converted to Forest Land*, *Cropland Remaining Cropland*, Land Converted to Cropland, Grassland Remaining Grassland, *Land Converted to Grassland*, *Wetlands Remaining Wetlands*, Land Converted to Wetlands, *Settlements Remaining Settlements*, and Land Converted to Settlements. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

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

Notes: Total(gross) emissions presented without LULUCF. Net emissions presented with LULUCF. 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	2016	2017	2018	2019	2020
CO_2	**5,122,496**	**6,137,603**	**5,251,758**	**5,210,958**	**5,376,657**	**5,259,144**	**4,715,691**
Fossil Fuel Combustion	4,731,178	5,752,043	4,909,609	4,853,299	4,989,308	4,852,330	4,342,659
Transportation	*1,468,944*	*1,858,552*	*1,757,638*	*1,779,977*	*1,812,761*	*1,813,755*	*1,572,034*
Electric Power Sector	*1,819,951*	*2,400,057*	*1,808,872*	*1,732,033*	*1,752,936*	*1,606,106*	*1,438,990*
Industrial	*853,707*	*851,522*	*792,743*	*790,402*	*814,096*	*816,107*	*766,317*
Residential	*338,578*	*358,898*	*292,773*	*293,410*	*338,218*	*341,400*	*315,846*
Commercial	*228,298*	*227,130*	*231,547*	*231,999*	*245,838*	*250,703*	*226,815*
U.S. Territories	*21,700*	*55,883*	*26,036*	*25,478*	*25,459*	*24,259*	*22,657*
Non-Energy Use of Fuels	112,175	128,920	99,505	112,616	128,871	126,776	120,987
Cement Production	33,484	46,194	39,439	40,324	38,971	40,896	40,688
Iron and Steel Production & Metallurgical Coke Production	104,737	70,076	43,621	40,566	42,627	43,090	37,731
Natural Gas Systems	31,894	24,945	29,780	31,145	32,407	38,740	35,353
Petroleum Systems	9,600	11,994	21,922	25,027	37,306	46,686	30,156
Petrochemical Production	21,611	27,383	28,110	28,890	29,314	30,702	30,011

Incineration of Waste	12,937	13,283	14,356	13,161	13,339	12,948	13,133
Ammonia Production	13,047	9,177	10,245	11,112	12,163	12,272	12,717
Lime Production	11,700	14,552	12,630	12,882	13,106	12,112	11,299
Other Process Uses of Carbonates	6,233	7,459	10,813	9,869	7,351	9,848	9,794
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	5,330	5,182	6,030	6,044	5,983
Urea Fertilization	2,417	3,504	4,679	4,897	5,019	5,140	5,275
Carbon Dioxide Consumption	1,472	1,375	4,640	4,580	4,130	4,870	4,970
Liming	4,667	4,349	3,081	3,080	2,248	2,413	2,382
Coal Mining	4,606	4,170	2,848	3,067	3,067	2,951	2,169
Glass Production	2,291	2,432	2,119	2,011	1,989	1,938	1,857
Aluminum Production	6,831	4,142	1,334	1,205	1,451	1,880	1,748
Soda Ash Production	1,431	1,655	1,723	1,753	1,714	1,792	1,461
Ferroalloy Production	2,152	1,392	1,796	1,975	2,063	1,598	1,377
Titanium Dioxide Production	1,195	1,755	1,662	1,688	1,541	1,474	1,340
Zinc Production	632	1,030	838	900	999	1,026	1,008
Phosphoric Acid Production	1,529	1,342	998	1,025	937	909	938
Lead Production	516	553	500	513	513	527	495
Carbide Production and Consumption	243	213	170	181	184	175	154
Abandoned Oil and Gas Wells	6	7	7	7	7	7	7
Magnesium Production and Processing	129	3	3	3	2	1	1
Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*219,413*	*230,700*	*316,853*	*312,717*	*319,805*	*317,231*	*291,613*
International Bunker Fuels[b]	*103,634*	*113,328*	*116,682*	*120,192*	*122,179*	*116,132*	*69,638*
CH_4[c]	**31,233**	**27,898**	**26,304**	**26,550**	**26,844**	**26,753**	**26,017**
Enteric Fermentation	6,539	6,722	6,853	6,998	7,028	7,046	7,007
Natural Gas Systems	7,821	7,100	6,609	6,662	6,871	6,885	6,596
Landfills	7,063	5,262	4,318	4,368	4,467	4,545	4,373
Manure Management	1,394	1,960	2,285	2,300	2,375	2,348	2,383
Coal Mining	3,860	2,565	2,154	2,191	2,109	1,895	1,648
Petroleum Systems	1,912	1,655	1,616	1,621	1,544	1,615	1,609
Wastewater Treatment	812	806	748	740	732	723	730
Rice Cultivation	640	720	631	596	623	602	630
Stationary Combustion	344	313	315	307	344	351	317
Abandoned Oil and Gas Wells	261	273	275	276	277	279	276
Abandoned Underground Coal Mines	288	264	268	257	247	237	231
Composting	15	75	91	98	90	91	91
Mobile Combustion	259	161	105	102	99	99	88
Field Burning of Agricultural Residues	15	17	17	17	17	17	17
Petrochemical Production	9	3	10	10	12	13	13
Anaerobic Digestion at Biogas Facilities	1	2	7	6	6	6	6
Carbide Production and Consumption	1	+	+	+	+	+	+
Ferroalloy Production	1	+	1	1	1	+	+
Iron and Steel Production & Metallurgical Coke Production	1	1	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*7*	*5*	*4*	*4*	*4*	*4*	*3*

N_2O[c]	**1,512**	**1,521**	**1,507**	**1,492**	**1,536**	**1,533**	**1,430**
Agricultural Soil Management	1,060	1,053	1,110	1,102	1,137	1,159	1,061
Wastewater Treatment	56	68	76	78	79	79	79
Stationary Combustion	84	115	101	95	95	84	78
Manure Management	47	55	62	64	65	65	66
Mobile Combustion	150	139	71	68	64	67	58
Nitric Acid Production	41	38	34	31	32	34	31
Adipic Acid Production	51	24	24	25	35	18	28
N_2O from Product Uses	14	14	14	14	14	14	14
Composting	1	6	7	7	7	7	7
Caprolactam, Glyoxal, and Glyoxylic Acid Production	6	7	6	5	5	5	4
Incineration of Waste	2	1	1	1	1	1	1
Electronics Industry	+	+	1	1	1	1	1
Field Burning of Agricultural Residues	1	1	1	1	1	1	1
Petroleum Systems	+	+	+	+	+	+	+
Natural Gas Systems	+	+	+	+	+	+	+
International Bunker Fuels[b]	*3*	*3*	*3*	*4*	*4*	*3*	*2*
HFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances[d]	M	M	M	M	M	M	M
HCFC-22 Production	3	1	+	+	+	+	+
Electronics Industry	M	M	M	M	M	M	M
Magnesium Production and Processing	NO	NO	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Electronics Industry	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M
Substitution of Ozone Depleting Substances[d]	NO	+	+	+	+	+	+
Electrical Transmission and Distribution	NO	+	+	+	NO	+	+
SF_6	**1**	**1**	**+**	**+**	**+**	**+**	**+**
Electrical Transmission and Distribution	1	+	+	+	+	+	+
Magnesium Production and Processing	+	+	+	+	+	+	+
Electronics Industry	+	+	+	+	+	+	+
NF_3	+	+	+	+	+	+	+
Electronics Industry	+	+	+	+	+	+	+
CO	**130,085**	**66,912**	**35,882**	**34,752**	**33,743**	**32,734**	**31,725**
NO_x	**21,712**	**17,191**	**8,686**	**8,296**	**7,869**	**7,374**	**6,883**
SO_2	**20,935**	**13,196**	**2,906**	**2,303**	**2,211**	**1,943**	**1,780**
NMVOCs	**20,923**	**13,309**	**9,855**	**9,483**	**9,310**	**9,136**	**8,963**

+ Does not exceed 0.5 kt.

M (Mixture of multiple gases)

NO (Not Occurring)

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

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

[c] LULUCF emissions of LULUCF CH_4 and N_2O are reported separately from gross emissions totals. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

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

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

Emissions of all gases can be summed from each source category into a set of five sectors defined by the Intergovernmental Panel on Climate Change (IPCC). Figure 2-3 and Table 2-3 illustrate that over the thirty-one-year period of 1990 to 2020, total emissions from the Energy and Waste sectors decreased by 486.5 MMT CO_2 Eq. (9.1 percent) and 58.6 MMT CO_2 Eq. (27.4 percent), respectively. Emissions from Industrial Processes and Product Use and Agriculture grew by 30.2 MMT CO_2 Eq. (8.7 percent) and 42.8 MMT CO_2 Eq. (7.8 percent), respectively. Over the same period, total C sequestration in the Land Use, Land-Use Change, and Forestry (LULUCF) sector decreased by 79.8 MMT CO_2 (9.0 percent decrease in total C sequestration), and emissions from the LULUCF sector increased by 21.8 MMT CO_2 Eq. (69.6 percent).

Figure 2-3: U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector

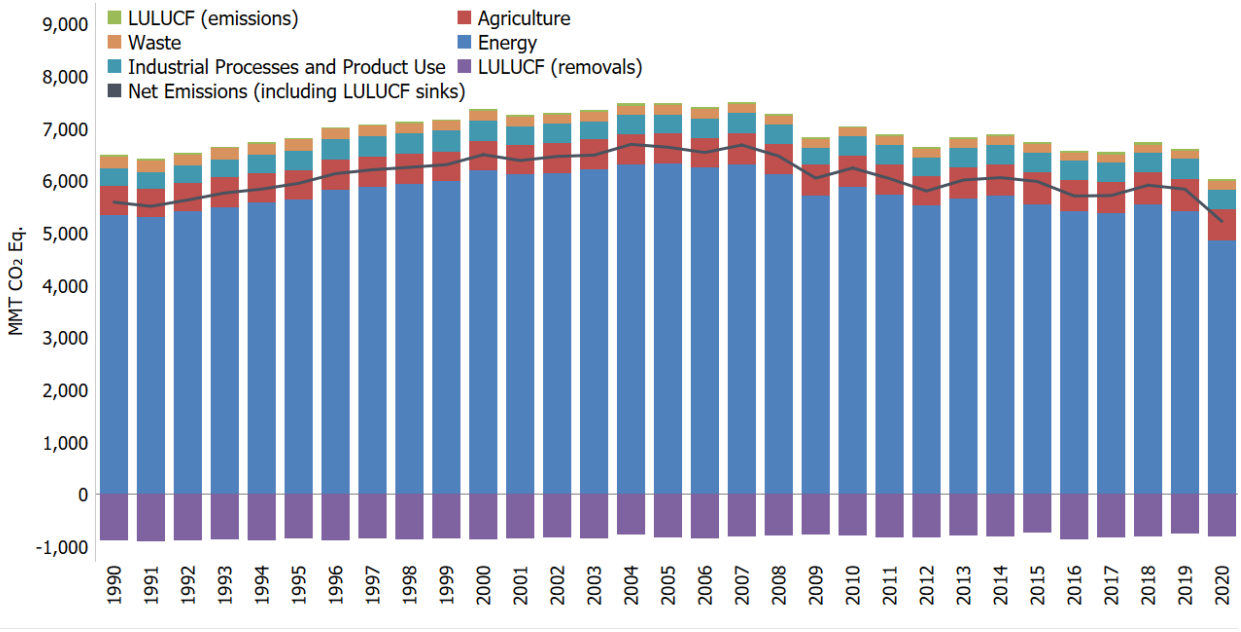


Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector/Category (MMT CO_2 Eq.)

IPCC Sector/Category	1990	2005	2016	2017	2018	2019	2020
Energy	**5,341.1**	**6,319.8**	**5,413.1**	**5,372.7**	**5,539.4**	**5,409.8**	**4,854.7**
Fossil Fuel Combustion	4,731.2	5,752.0	4,909.6	4,853.3	4,989.3	4,852.3	4,342.7
Natural Gas Systems	227.4	202.5	195.0	197.7	204.2	210.9	200.3
Non-Energy Use of Fuels	112.2	128.9	99.5	112.6	128.9	126.8	121.0
Petroleum Systems	57.4	53.4	62.3	65.6	75.9	87.1	70.4
Coal Mining	101.1	68.3	56.7	57.9	55.8	50.3	43.4
Stationary Combustion[a]	33.7	42.2	37.9	36.1	36.8	33.7	31.2
Mobile Combustion[a]	51.1	45.4	23.7	22.7	21.6	22.4	19.6
Incineration of Waste	13.4	13.7	14.8	13.6	13.8	13.4	13.5
Abandoned Oil and Gas Wells	6.5	6.8	6.9	6.9	6.9	7.0	6.9
Abandoned Underground Coal Mines	7.2	6.6	6.7	6.4	6.2	5.9	5.8
Industrial Processes and Product Use	**346.2**	**365.9**	**369.0**	**369.4**	**373.4**	**379.5**	**376.4**
Substitution of Ozone Depleting Substances	0.2	107.2	165.1	165.5	167.3	171.8	176.3
Cement Production	33.5	46.2	39.4	40.3	39.0	40.9	40.7

Iron and Steel Production & Metallurgical Coke Production	104.8	70.1	43.6	40.6	42.6	43.1	37.7
Petrochemical Production	21.8	27.5	28.4	29.1	29.6	31.0	30.3
Ammonia Production	13.0	9.2	10.2	11.1	12.2	12.3	12.7
Lime Production	11.7	14.6	12.6	12.9	13.1	12.1	11.3
Other Process Uses of Carbonates	6.2	7.5	10.8	9.9	7.4	9.8	9.8
Nitric Acid Production	12.1	11.3	10.1	9.3	9.6	10.0	9.3
Adipic Acid Production	15.2	7.1	7.1	7.5	10.5	5.3	8.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	5.3	5.2	6.0	6.0	6.0
Carbon Dioxide Consumption	1.5	1.4	4.6	4.6	4.1	4.9	5.0
Electronics Industry	3.6	4.8	5.0	4.9	5.1	4.7	4.7
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Electrical Transmission and Distribution	23.2	8.4	4.1	4.2	3.8	4.2	3.8
Aluminum Production	28.3	7.6	2.7	2.3	3.1	3.6	3.4
HCFC-22 Production	46.1	20.0	2.8	5.2	3.3	3.7	2.1
Glass Production	2.3	2.4	2.1	2.0	2.0	1.9	1.9
Soda Ash Production	1.4	1.7	1.7	1.8	1.7	1.8	1.5
Ferroalloy Production	2.2	1.4	1.8	2.0	2.1	1.6	1.4
Titanium Dioxide Production	1.2	1.8	1.7	1.7	1.5	1.5	1.3
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	1.7	1.5	1.4	1.4	1.2
Zinc Production	0.6	1.0	0.8	0.9	1.0	1.0	1.0
Phosphoric Acid Production	1.5	1.3	1.0	1.0	0.9	0.9	0.9
Magnesium Production and Processing	5.3	2.7	1.2	1.1	1.1	0.9	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Carbide Production and Consumption	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	**551.9**	**573.6**	**601.9**	**603.2**	**616.7**	**622.9**	**594.7**
Agricultural Soil Management	316.0	313.8	330.8	328.3	338.9	345.3	316.2
Enteric Fermentation	163.5	168.0	171.3	174.9	175.7	176.1	175.2
Manure Management	48.8	65.3	75.5	76.5	78.7	78.2	79.2
Rice Cultivation	16.0	18.0	15.8	14.9	15.6	15.1	15.7
Urea Fertilization	2.4	3.5	4.7	4.9	5.0	5.1	5.3
Liming	4.7	4.3	3.1	3.1	2.2	2.4	2.4
Field Burning of Agricultural Residues	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Waste	**214.2**	**175.6**	**153.9**	**155.7**	**157.9**	**159.6**	**155.6**
Landfills	176.6	131.5	107.9	109.2	111.7	113.6	109.3
Wastewater Treatment	36.9	40.5	41.5	41.7	41.8	41.5	41.8
Composting	0.7	3.5	4.3	4.6	4.3	4.3	4.3
Anaerobic Digestion at Biogas Facilities	+	+	0.2	0.2	0.2	0.2	0.2
Total Gross Emissions[b] (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**
LULUCF Sector Net Total[c]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**
Forest land	(868.3)	(773.0)	(816.7)	(769.6)	(764.2)	(731.4)	(741.7)
Cropland	28.6	23.0	31.4	32.0	37.4	39.4	31.0
Grassland	4.0	(27.6)	(14.0)	(12.7)	(12.1)	(8.4)	(19.0)
Wetlands	21.9	18.5	16.5	16.6	16.5	16.5	16.5
Settlements	(46.8)	(30.7)	(43.8)	(47.4)	(46.9)	(46.6)	(45.8)
Net Emission (Sources and Sinks)[d]	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Includes CH_4 and N_2O emissions from fuel combustion.

[b] Total emissions without LULUCF.

[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals. LULUCF emissions include the CH_4 and N_2O emissions reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands,* Flooded Land Remaining Flooded Land, and Land Converted to Flooded Land; and N_2O emissions from Forest Soils and Settlement Soils. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

[d] Net emissions with LULUCF.

Notes: Total (gross) emissions presented without LULUCF. Net emissions presented with LULUCF. 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 2020. Fossil fuel combustion is the largest source of energy-related emissions, with CO_2 being the primary gas emitted (see Figure 2-4). Due to their relative importance, fossil fuel combustion-related CO_2 emissions are considered in detail in the Energy chapter (see Energy chapter).

In 2020, 78.8 percent of the energy used in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 21.2 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy. A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy use is presented here with more detail in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (41.4 percent and 9.6 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 2-4: Trends in Energy Sector Greenhouse Gas Sources

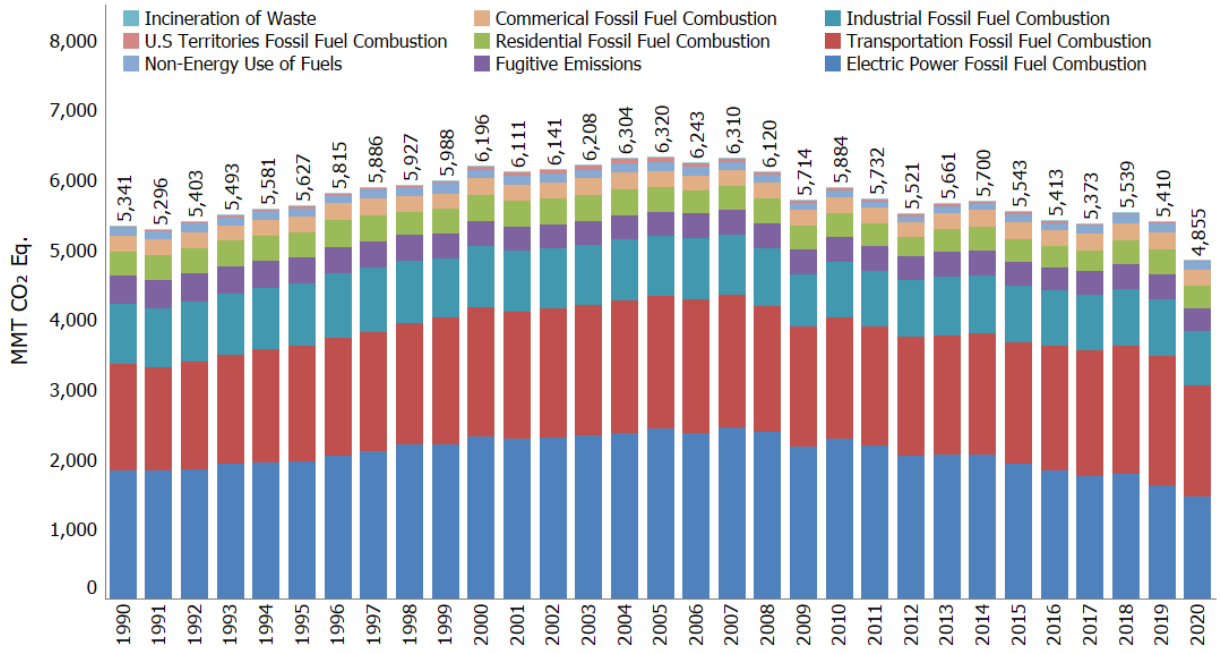


Table 2-4: Emissions from Energy (MMT CO_2 Eq.)[2]

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CO_2	4,902.4	5,935.4	5,078.0	5,038.3	5,204.3	5,080.4	4,544.5

[2] The full time series data is available in Common Reporting Format (CRF) Tables included in the U.S. UNFCCC submission and in CSV format available at https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Fossil Fuel Combustion	4,731.2	5,752.0	4,909.6	4,853.3	4,989.3	4,852.3	4,342.7
Transportation	*1,468.9*	*1,858.6*	*1,757.6*	*1,780.0*	*1,812.8*	*1,813.8*	*1,572.0*
Electricity Generation	*1,820.0*	*2,400.1*	*1,808.9*	*1,732.0*	*1,752.9*	*1,606.1*	*1,439.0*
Industrial	*853.7*	*851.5*	*792.7*	*790.4*	*814.1*	*816.1*	*766.3*
Residential	*338.6*	*358.9*	*292.8*	*293.4*	*338.2*	*341.4*	*315.8*
Commercial	*228.3*	*227.1*	*231.5*	*232.0*	*245.8*	*250.7*	*226.8*
U.S. Territories	*21.7*	*55.9*	*26.0*	*25.5*	*25.5*	*24.3*	*22.7*
Non-Energy Use of Fuels	112.2	128.9	99.5	112.6	128.9	126.8	121.0
Natural Gas Systems	31.9	24.9	29.8	31.1	32.4	38.7	35.4
Petroleum Systems	9.6	12.0	21.9	25.0	37.3	46.7	30.2
Incineration of Waste	12.9	13.3	14.4	13.2	13.3	12.9	13.1
Coal Mining	4.6	4.2	2.8	3.1	3.1	3.0	2.2
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Biomass-Wood [a]	*215.2*	*206.9*	*216.0*	*211.9*	*220.0*	*217.6*	*202.1*
Biofuels-Ethanol [a]	*4.2*	*22.9*	*81.2*	*82.1*	*81.9*	*82.6*	*71.8*
International Bunker Fuels[b]	*103.6*	*113.3*	*116.7*	*120.2*	*122.2*	*116.1*	*69.6*
Biofuels-Biodiesel [a]	*0.0*	*0.9*	*19.6*	*18.7*	*17.9*	*17.1*	*17.7*
CH_4	**368.6**	**308.3**	**283.5**	**285.4**	**287.3**	**284.0**	**269.1**
Natural Gas Systems	195.5	177.5	165.2	166.6	171.8	172.1	164.9
Coal Mining	96.5	64.1	53.8	54.8	52.7	47.4	41.2
Petroleum Systems	47.8	41.4	40.4	40.5	38.6	40.4	40.2
Stationary Combustion	8.6	7.8	7.9	7.7	8.6	8.8	7.9
Abandoned Oil and Gas Wells	6.5	6.8	6.9	6.9	6.9	7.0	6.9
Abandoned Underground Coal Mines	7.2	6.6	6.7	6.4	6.2	5.9	5.8
Mobile Combustion	6.5	4.0	2.6	2.6	2.5	2.5	2.2
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**70.1**	**76.1**	**51.5**	**49.0**	**47.9**	**45.3**	**41.1**
Stationary Combustion	25.1	34.4	30.0	28.4	28.2	24.9	23.2
Mobile Combustion	44.6	41.4	21.1	20.1	19.2	20.0	17.4
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Petroleum Systems	+	+	+	+	+	+	+
Natural Gas Systems	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.9*	*1.0*	*1.0*	*1.1*	*1.1*	*1.0*	*0.6*
Total	**5,341.1**	**6,319.8**	**5,413.1**	**5,372.7**	**5,539.4**	**5,409.8**	**4,854.7**

+ Does not exceed 0.05 MMT CO_2 Eq.

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

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

Note: Totals may not sum due to independent rounding.

CO_2 Emissions from Fossil Fuel Combustion

As the largest contributor to U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 75.3 percent of gross emissions across the time series. Within the United States, fossil fuel combustion accounted for 92.1 percent of CO_2 emissions in 2020. Emissions from this source category decreased by 8.2 percent (388.5 MMT CO_2 Eq.) from 1990 to 2020 and were responsible for most of the decrease in national emissions during this period. Similarly, CO_2 emissions from fossil fuel combustion decreased by 1,409.4 MMT CO_2 Eq. from 2005 and by 1,003.0 MMT CO_2 Eq. from 2010, representing decreases of 24.5 percent between 2005 and 2020 and 18.8 percent between 2010 and 2020. From 2019 to 2020, these emissions decreased by 10.5 percent (509.7 MMT CO_2 Eq.). Historically, changes in emissions from fossil fuel combustion have been the main factor influencing U.S. emission trends.

Changes in CO_2 emissions from fossil fuel combustion since 1990 are affected by many long-term and short-term factors, including population and economic growth, energy price fluctuations and market trends, technological changes, carbon intensity of energy fuel choices, and seasonal temperatures. CO_2 emissions from coal combustion gradually increased between 1990 and 2007, then began to decrease at a faster rate from 2008 to 2020. CO_2 emissions from natural gas combustion remained relatively constant, with a slight increase between 1990 and 2009, then began to consistently increase between 2010 and 2019. The replacement of coal combustion with natural gas combustion was largely driven by new discoveries of natural gas fields and advancements in drilling technologies, which led to more competitive natural gas prices. On an annual basis, the overall consumption and mix of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, overall energy prices, the relative price of different fuels, weather, and the availability of non-fossil alternatives. For example, coal consumption for electric power is influenced by a number of factors, including the relative price of coal and alternative sources, the ability to switch fuels, and longer-term trends in coal markets. Likewise, warmer winters lead to a decrease in heating degree days and result in a decreased demand for heating fuel and electricity for heat in the residential and commercial sectors, which leads to a decrease in emissions from reduced fuel consumption. The decrease in 2020 emissions was due primarily to the COVID-19 pandemic reducing overall demand for fossil fuels across all sectors, but it also reflects a continued shift from coal to natural gas and renewables in the electric power sector.

Fossil fuel combustion CO_2 emissions also depend on the type of fuel consumed or energy used and its carbon intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, reduces CO_2 emissions because of the lower C content of natural gas (see Table A-22 in Annex 2.1 for more detail on the C Content Coefficient of different fossil fuels).

Recent trends in CO_2 emissions from fossil fuel combustion have been strongly influenced by trends in the electric power sector, which from 1990 to 2017 accounted for the largest share of emissions from this source (see Figure 2-12). Electric power sector emissions are driven by the total amount of electricity generated to meet electricity demand and the carbon intensity of the energy mix used to produce the electricity. From 1990 to 2005, power sector CO_2 emissions increased 31.9 percent with a 34.3 percent increase in generation (see Figure 2-7). From 2005 to 2020, power sector CO_2 emissions dropped 40.0 percent while generation remained relatively flat (a 1.4 percent decrease). The types of fuel consumed to produce electricity have shifted over time, impacting emission trends. Electricity generation from lower carbon intensity renewable energy sources increased by 132.3 percent from 2005 to 2020 and natural gas generation increased by 122.2 percent while coal generation decreased by 61.5 percent over the same time period (see Table 3-12 for more detail on electricity generation by source). The decrease in coal-powered electricity generation and increase in natural gas and renewable energy electricity generation have contributed to the 40.0 percent decrease in overall CO_2 emissions from electric power generation from 2005 to 2020 (see Figure 2-7). Between 2019 and 2020, emissions from the electric power sector decreased 10.4 percent due to a decrease in electric power generation of 2.9 percent and a decrease in the carbon intensity of the electric power energy mix reflecting the continued shift in the share of electric power generation from coal to natural gas and renewable energy.

Petroleum use is another major driver of CO_2 emissions from fossil fuel combustion, particularly in the transportation sector, which has represented the largest source of CO_2 emissions from fossil fuel combustion since 2018. Emissions from petroleum consumption for transportation (including bunker fuels) have decreased by 11.9 percent since 2016; this trend can be primarily attributed to a 11.0 percent decrease in vehicle miles traveled (VMT) from 2019 to 2020, due largely to the impacts of the coronavirus pandemic which limited travel in 2020. Fuel economy of light-duty vehicles is another important factor. The decline in new light-duty vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light-duty trucks, which grew from about 30 percent of new vehicle sales in 1990 to 48 percent in 2004. Starting in 2005, average new vehicle fuel economy began to increase while light-duty VMT grew only modestly for much of the period and has slowed the rate of increase of CO_2 emissions.

Overall, across all sectors, there was a 10.5 percent decrease in total CO_2 emissions from fossil fuel combustion from 2019 to 2020 and a 11.5 percent reduction since 2016. Trends in carbon dioxide emissions from fossil fuel combustion, separated by end-use sector, are presented in Table 2-5 and Figure 2-5 based on the underlying U.S. energy consumer data collected by the U.S. Energy Information Administration (EIA). Figure 2-6 further describes

trends in direct and indirect CO_2 emissions from fossil fuel combustion, separated by end-use sector. Estimates of CO_2 emissions from fossil fuel combustion are calculated from these EIA "end-use sectors" based on total fuel consumption and appropriate fuel properties described below. (Any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report.)

- *Transportation.* EIA's fuel consumption data for the transportation sector consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another.
- *Industry.* EIA statistics for the industrial sector include fossil fuel consumption that occurs in the fields of manufacturing, agriculture, mining, and construction. EIA's fuel consumption data for the industrial sector consist of all facilities and equipment used for producing, processing, or assembling goods. (EIA includes generators that produce electricity and/or useful thermal output primarily to support on-site industrial activities in this sector.)
- *Electric Power.* EIA's fuel consumption data for the electric power sector are comprised of electricity-only and combined-heat-and-power (CHP) plants within the North American Industry Classification System (NAICS) 22 category whose primary business is to sell electricity, or electricity and heat, to the public. (Non-utility power producers are included in this sector as long as they meet the electric power sector definition.)
- *Residential.* EIA's fuel consumption data for the residential sector consist of living quarters for private households.
- *Commercial.* EIA's fuel consumption data for the commercial sector consist of service-providing facilities and equipment from private and public organizations and businesses. (EIA includes generators that produce electricity and/or useful thermal output primarily to support the activities at commercial establishments in this sector.)

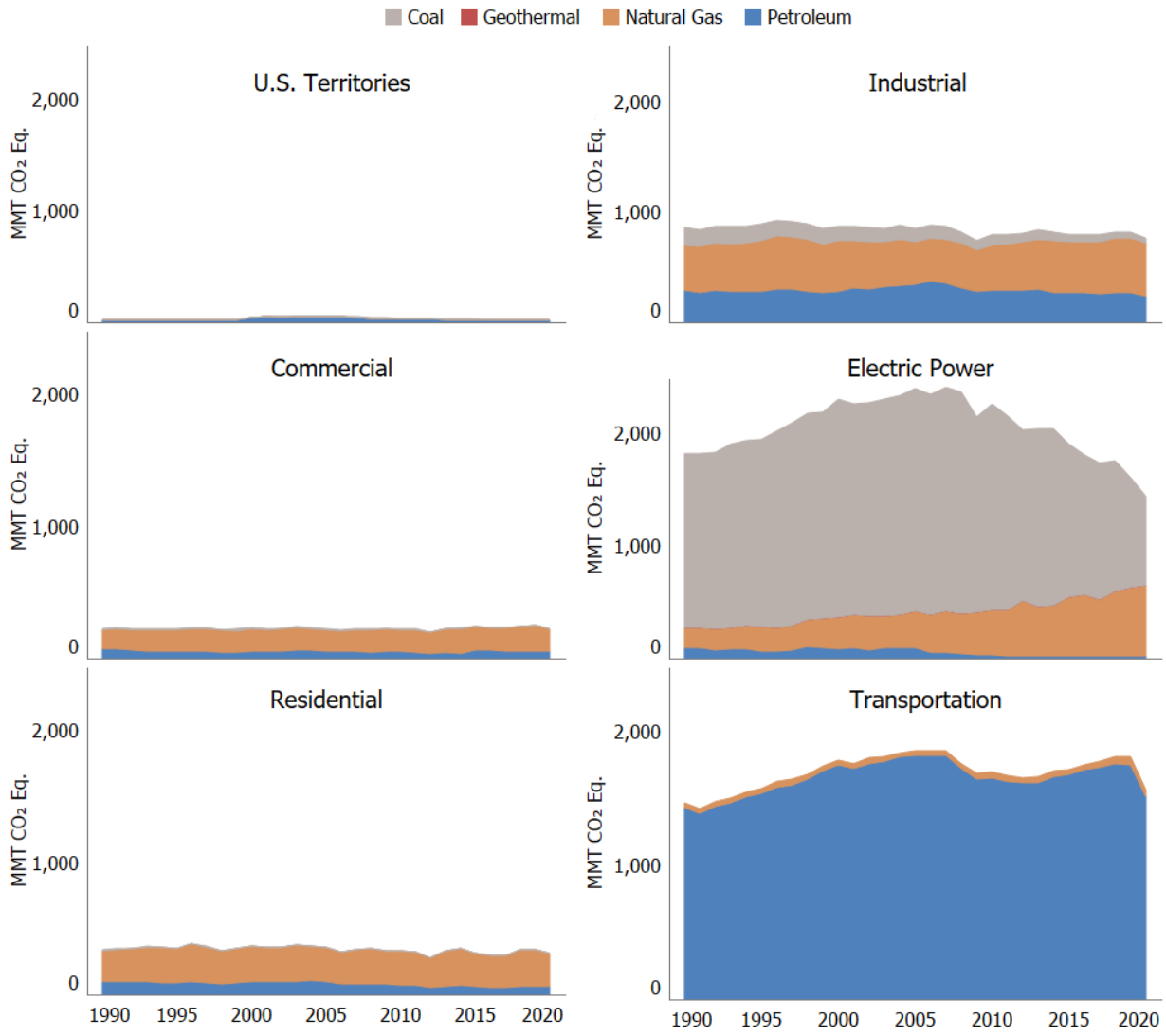
Table 2-5: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (MMT CO_2 Eq.)

End-Use Sector	1990	2005	2016	2017	2018	2019	2020
Transportation	**1,472.0**	**1,863.3**	**1,761.8**	**1,784.3**	**1,817.4**	**1,818.5**	**1,576.7**
Combustion	1,468.9	1,858.6	1,757.6	1,780.0	1,812.8	1,813.8	1,572.0
Electricity	3.0	4.7	4.2	4.3	4.7	4.7	4.7
Industrial	**1,540.1**	**1,587.8**	**1,310.3**	**1,294.8**	**1,315.3**	**1,281.4**	**1,175.8**
Combustion	853.7	851.5	792.7	790.4	814.1	816.1	766.3
Electricity	686.4	736.3	517.6	504.4	501.2	465.3	409.5
Residential	**931.3**	**1,214.9**	**946.2**	**910.5**	**980.4**	**925.0**	**860.6**
Combustion	338.6	358.9	292.8	293.4	338.2	341.4	315.8
Electricity	592.7	856.0	653.5	617.1	642.2	583.6	544.8
Commercial	**766.0**	**1,030.1**	**865.2**	**838.2**	**850.7**	**803.2**	**706.8**
Combustion	228.3	227.1	231.5	232.0	245.8	250.7	226.8
Electricity	537.7	803.0	633.6	606.2	604.9	552.5	480.0
U.S. Territories[a]	**21.7**	**55.9**	**26.0**	**25.5**	**25.5**	**24.3**	**22.7**
Total	**4,731.2**	**5,752.0**	**4,909.6**	**4,853.3**	**4,989.3**	**4,852.3**	**4,342.7**
Electric Power	**1,820.0**	**2,400.1**	**1,808.9**	**1,732.0**	**1,752.9**	**1,606.1**	**1,439.0**

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

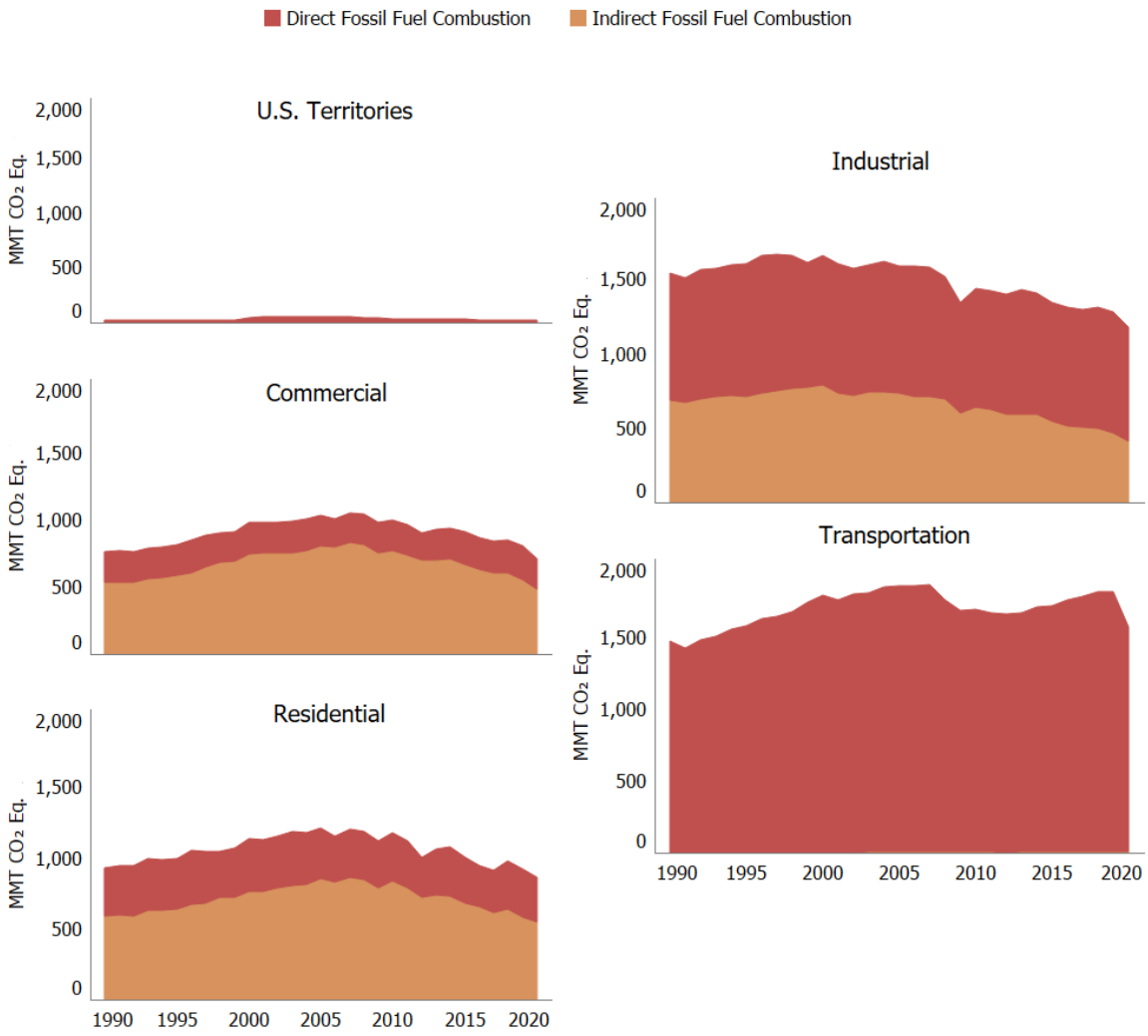
Notes: Combustion-related emissions from electric power are allocated based on aggregate national electricity use by each end-use sector. Totals may not sum due to independent rounding.

Figure 2-5: Trends in CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector and Fuel Type



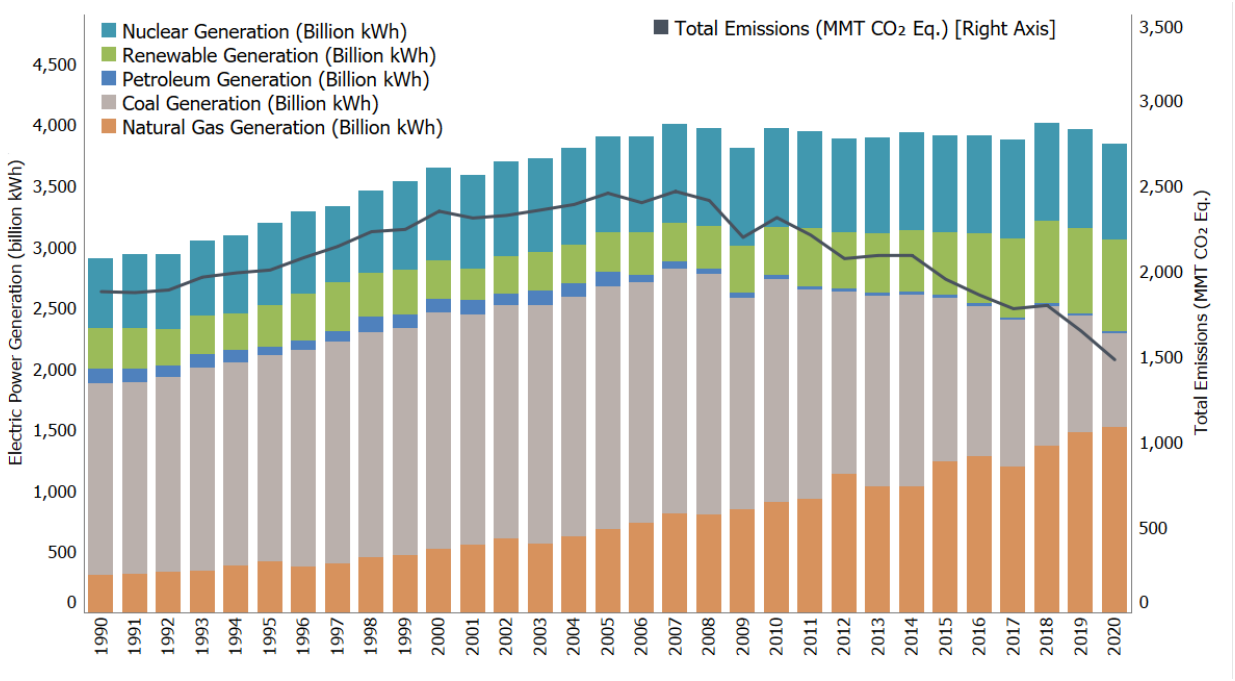
Note on Figure 2-5: Fossil Fuel Combustion for electric power also includes emissions of less than 0.5 MMT CO_2 Eq. from geothermal-based generation.

Figure 2-6: Trends in End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion



Electric power was the second largest emitter of CO_2 in 2020 (surpassed by transportation); electric power generators used 31.2 percent of U.S. energy from fossil fuels and emitted 33.1 percent of the CO_2 from fossil fuel combustion in 2020. Changes in electricity demand and the carbon intensity of fuels used for electric power generation have a significant impact on CO_2 emissions. Carbon dioxide emissions from fossil fuel combustion from the electric power sector have decreased by 20.9 percent since 1990, and the carbon intensity of the electric power sector, in terms of CO_2 Eq. per QBtu input, has significantly decreased by 19.2 percent during that same timeframe. This decoupling of electric power generation and the resulting CO_2 emissions is shown below in Figure 2-7.

Figure 2-7: Electric Power Generation (Billion kWh) and Emissions (MMT CO_2 Eq.)



Electric power CO_2 emissions can also be allocated to the end-use sectors that use electricity, as presented in Table 2-5. With electricity CO_2 emissions allocated to end-use sectors, the transportation end-use sector represents the largest source of fossil fuel combustion emissions accounting for 1,576.7 MMT CO_2 Eq. in 2020 or 36.3 percent of total CO_2 emissions from fossil fuel combustion. The industrial end-use sector accounted for 27.1 percent of CO_2 emissions from fossil fuel combustion when including allocated electricity emissions. The residential and commercial end-use sectors accounted for 19.8 and 16.3 percent, respectively, of CO_2 emissions from fossil fuel combustion when including allocated electricity emissions. Both of these end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity use for lighting, heating, air conditioning, and operating appliances contributing 63.3 and 67.9 percent of emissions from the residential and commercial end-use sectors, respectively.

Other Significant Trends in Energy

Other significant trends in emissions from energy source categories (Figure 2-5 and Figure 2-6) over the thirty-one-year period from 1990 through 2020 included the following:

- Methane emissions from natural gas systems and petroleum systems (combined here) decreased 38.2 MMT CO_2 Eq. (15.7 percent decrease from 1990 to 2020) or from 243.3 MMT CO_2 Eq. in 1990 to 205.1 MMT CO_2 Eq. in 2020. Natural gas systems CH_4 emissions decreased by 30.6 MMT CO_2 Eq. (15.7 percent) since 1990, largely due to a decrease in emissions from distribution, transmission and storage, processing, and exploration. The decrease in distribution is largely due to decreased emissions from pipelines and distribution station leaks, and the decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and leaks). At the same time, emissions from the natural gas production segment increased. Petroleum systems CH_4 emissions decreased by 7.6 MMT CO_2 Eq. (or 15.8 percent) since 1990. This decrease is due primarily to decreases in emissions from offshore platforms, tanks, and pneumatic controllers. Carbon dioxide emissions from natural gas and petroleum systems increased by 24.0 MMT CO_2 Eq. (57.9 percent) from 1990 to 2020. This increase is due primarily to increases in the production segment, where flaring emissions from associated gas flaring, tanks, and miscellaneous production flaring have increased over time.

- Methane emissions from coal mining decreased by 55.3 MMT CO_2 Eq. (57.3 percent) from 1990 through 2020, primarily due to a decrease in the number of active mines and annual coal production over the time period.
- Nitrous oxide emissions from mobile combustion decreased by 27.2 MMT CO_2 Eq. (61.0 percent) from 1990 through 2020, primarily as a result of national vehicle criteria pollutant emissions standards and emission control technologies for on-road vehicles.
- Carbon dioxide emissions from non-energy uses of fossil fuels increased by 8.8 MMT CO_2 Eq. (7.9 percent) from 1990 through 2020. Emissions from non-energy uses of fossil fuels were 121.0 MMT CO_2 Eq. in 2020, which constituted 2.6 percent of total national CO_2 emissions, approximately the same proportion as in 1990.
- Carbon dioxide emissions from incineration of waste (13.1 MMT CO_2 Eq. in 2020) increased slightly by 0.2 MMT CO_2 Eq. (1.5 percent) from 1990 through 2020, as the volume of scrap tires and other fossil C-containing materials in waste increased.

Industrial Processes and Product Use

Greenhouse gases can be generated and emitted by industry in two different ways. First, they are generated and emitted as the byproducts of many non-energy-related industrial activities. For example, industrial processes can chemically or physically transform raw materials, which often release waste gases such as CO_2, CH_4, N_2O, and fluorinated gases (e.g., HFC-23). In the case of byproduct emissions, the emissions are generated by an industrial process itself, and are not directly a result of energy consumed during the process.

Second, industrial manufacturing processes and use by end-consumers also release HFCs, PFCs, SF_6, and NF_3 and other fluorinated compounds. In addition to the use of HFCs and some PFCs as substitutes for ozone depleting substances (ODS), fluorinated compounds such as HFCs, PFCs, SF_6, NF_3, and others are also emitted through use by a number of other industrial sources in the United States. These industries include the electronics industry, electric power transmission and distribution, and magnesium metal production and processing. In addition, N_2O is used in and emitted by the electronics industry and anesthetic and aerosol applications, and CO_2 is consumed and emitted through various end-use applications.

Emission sources in the Industrial Processes and Product Use (IPPU) chapter accounted for 6.3 percent of U.S. greenhouse gas emissions in 2020. Emissions from the IPPU sector increased by 8.7 percent from 1990 to 2020. Total emissions from IPPU remained relatively constant between 2019 and 2020, decreasing 0.8 percent due to offsetting trends within the sector. Some industrial processes and product use categories experienced decreases due to impacts from the COVID-19 pandemic (e.g., Iron and Steel Production and Lime Production), while other categories experienced increases in emissions from 2019 to 2020 (e.g., Ammonia Production and the Substitution of Ozone Depleting Substances). Figure 2-8 presents greenhouse gas emissions from IPPU by source category.

Figure 2-8: Trends in Industrial Processes and Product Use Sector Greenhouse Gas Sources

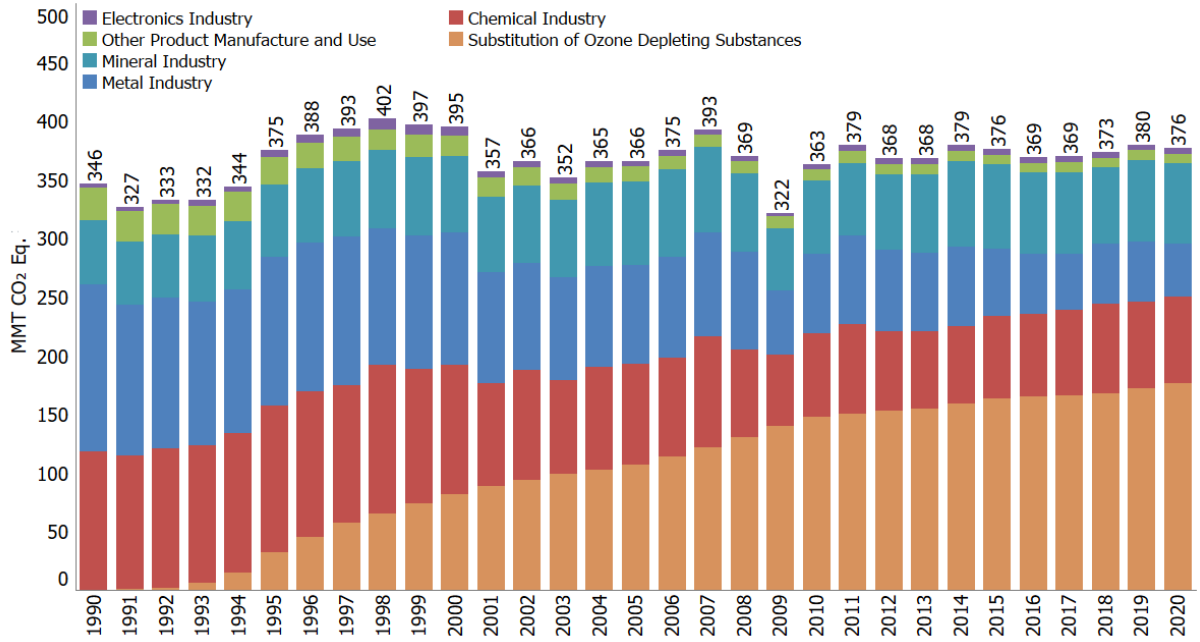


Table 2-6: Emissions from Industrial Processes and Product Use (MMT CO_2 Eq.)

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CO_2	**213.0**	**194.4**	**166.0**	**164.7**	**165.1**	**171.2**	**163.6**
Iron and Steel Production & Metallurgical Coke Production	104.7	70.1	43.6	40.6	42.6	43.1	37.7
Iron and Steel Production	*99.1*	*66.2*	*41.0*	*38.6*	*41.3*	*40.1*	*35.4*
Metallurgical Coke Production	*5.6*	*3.9*	*2.6*	*2.0*	*1.3*	*3.0*	*2.3*
Cement Production	33.5	46.2	39.4	40.3	39.0	40.9	40.7
Petrochemical Production	21.6	27.4	28.1	28.9	29.3	30.7	30.0
Ammonia Production	13.0	9.2	10.2	11.1	12.2	12.3	12.7
Lime Production	11.7	14.6	12.6	12.9	13.1	12.1	11.3
Other Process Uses of Carbonates	6.2	7.5	10.8	9.9	7.4	9.8	9.8
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	5.3	5.2	6.0	6.0	6.0
Carbon Dioxide Consumption	1.5	1.4	4.6	4.6	4.1	4.9	5.0
Glass Production	2.3	2.4	2.1	2.0	2.0	1.9	1.9
Aluminum Production	6.8	4.1	1.3	1.2	1.5	1.9	1.7
Soda Ash Production	1.4	1.7	1.7	1.8	1.7	1.8	1.5
Ferroalloy Production	2.2	1.4	1.8	2.0	2.1	1.6	1.4
Titanium Dioxide Production	1.2	1.8	1.7	1.7	1.5	1.5	1.3
Zinc Production	0.6	1.0	0.8	0.9	1.0	1.0	1.0
Phosphoric Acid Production	1.5	1.3	1.0	1.0	0.9	0.9	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Carbide Production and Consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	0.1	+	+	+	+	+	+
CH_4	**0.3**	**0.1**	**0.3**	**0.3**	**0.3**	**0.4**	**0.3**
Petrochemical Production	0.2	0.1	0.2	0.3	0.3	0.3	0.3
Carbide Production and Consumption	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Iron and Steel Production	*+*	*+*	*+*	*+*	*+*	*+*	*+*

Metallurgical Coke Production	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
N_2O	**33.3**	**24.9**	**23.4**	**22.7**	**26.0**	**21.1**	**23.3**
Nitric Acid Production	12.1	11.3	10.1	9.3	9.6	10.0	9.3
Adipic Acid Production	15.2	7.1	7.1	7.5	10.5	5.3	8.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	1.7	1.5	1.4	1.4	1.2
Electronics Industry	+	0.1	0.2	0.3	0.3	0.2	0.3
HFCs	**46.5**	**127.4**	**168.3**	**171.1**	**171.0**	**175.9**	**178.8**
Substitution of Ozone Depleting Substances[a]	0.2	107.2	165.1	165.5	167.3	171.8	176.2
HCFC-22 Production	46.1	20.0	2.8	5.2	3.3	3.7	2.1
Electronics Industry	0.2	0.2	0.3	0.4	0.4	0.4	0.4
Magnesium Production and Processing	NO	NO	0.1	0.1	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**4.4**	**4.2**	**4.8**	**4.6**	**4.4**
Electronics Industry	2.8	3.3	3.0	3.0	3.1	2.8	2.7
Aluminum Production	21.5	3.4	1.4	1.1	1.6	1.8	1.7
Substitution of Ozone Depleting Substances	NO	+	+	+	0.1	0.1	0.1
Electrical Transmission and Distribution	NO	+	+	+	NO	+	+
SF_6	**28.8**	**11.8**	**6.0**	**5.9**	**5.7**	**5.9**	**5.4**
Electrical Transmission and Distribution	23.2	8.3	4.1	4.2	3.8	4.2	3.8
Magnesium Production and Processing	5.2	2.7	1.1	1.0	1.0	0.9	0.9
Electronics Industry	0.5	0.7	0.8	0.7	0.8	0.8	0.7
NF_3	**+**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Electronics Industry	+	0.5	0.6	0.6	0.6	0.6	0.6
Total	**346.2**	**365.9**	**369.0**	**369.4**	**373.4**	**379.5**	**376.4**

+ Does not exceed 0.05 MMT CO_2 Eq.

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

NO (Not Occurring)

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from IPPU source categories over the thirty-one-year period from 1990 through 2020 included the following:

- HFC and PFC emissions resulting from the substitution of ODS (e.g., chlorofluorocarbons [CFCs]) have been increasing from small amounts in 1990 to 176.3 MMT CO_2 Eq. in 2020 and accounted for 46.8 percent of total IPPU emissions.
- Combined CO_2 and CH_4 emissions from iron and steel production and metallurgical coke production decreased by 12.4 percent from 2019 to 2020 to 37.7 MMT CO_2 Eq. and have declined overall by 67.0 MMT CO_2 Eq. (64.0 percent) from 1990 through 2020, due to restructuring of the industry. The trend in the United States has been a shift towards fewer integrated steel mills and more electric arc furnaces (EAFs). EAFs use scrap steel as their main input and generally have less on-site emissions.
- Carbon dioxide emissions from petrochemicals increased by 38.9 percent between 1990 and 2020 from 21.6 MMT CO_2 Eq. to 30.0 MMT CO_2 Eq. The increase in emissions is largely driven by a doubling of production of ethylene over that time period.
- Carbon dioxide emissions from ammonia production (12.7 MMT CO_2 Eq. in 2020) decreased by 2.5 percent (0.3 MMT CO_2 Eq.) 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 from year to year. Emissions from ammonia production have increased steadily since 2016, due to the addition of new ammonia production facilities and new production units at existing facilities. Agricultural demands continue to drive demand for nitrogen fertilizers and the need for new ammonia production capacity.
- Carbon dioxide emissions from cement production increased by 21.5 percent (7.2 MMT CO_2 Eq.) from 1990 through 2020. They rose from 1990 through 2006 and then fell until 2009, due to a decrease in

demand for construction materials during the economic recession. Since 2010, CO_2 emissions from cement production have risen 29.4 percent (9.2 MMT CO_2 Eq.).

- Carbon dioxide emissions from lime production decreased by 6.7 percent (0.8 MMT CO_2) from 2019 to 2020. Compared to 1990, CO_2 emissions have decreased by about 3.4 percent. The trends in CO_2 emissions from lime production are directly proportional to trends in lime production and since 2015, fluctuation in lime production has been driven by demand from the steel making industry.
- PFC emissions from aluminum production decreased by 92.2 percent (19.8 MMT CO_2 Eq.) from 1990 to 2020, due to both industry emission reduction efforts and lower domestic aluminum production.

Agriculture

Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, liming, urea fertilization, and field burning of agricultural residues. Methane, N_2O, and CO_2 were the primary greenhouse gases emitted by agricultural activities. Carbon stock changes from agricultural soils are included in the LULUCF sector.

In 2020, agricultural activities were responsible for emissions of 594.7 MMT CO_2 Eq., or 9.9 percent of total U.S. greenhouse gas emissions. Methane emissions from enteric fermentation and manure management represented 26.9 percent and 9.2 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2020. Agricultural soil management activities, such as application of synthetic and organic fertilizers, deposition of livestock manure, and growing N-fixing plants, were the largest contributors to U.S. N_2O emissions in 2020, accounting for 74.2 percent. Carbon dioxide emissions from the application of crushed limestone and dolomite (i.e., soil liming) and urea fertilization represented 0.2 percent of total CO_2 emissions from anthropogenic activities. Figure 2-9 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

Figure 2-9: Trends in Agriculture Sector Greenhouse Gas Sources

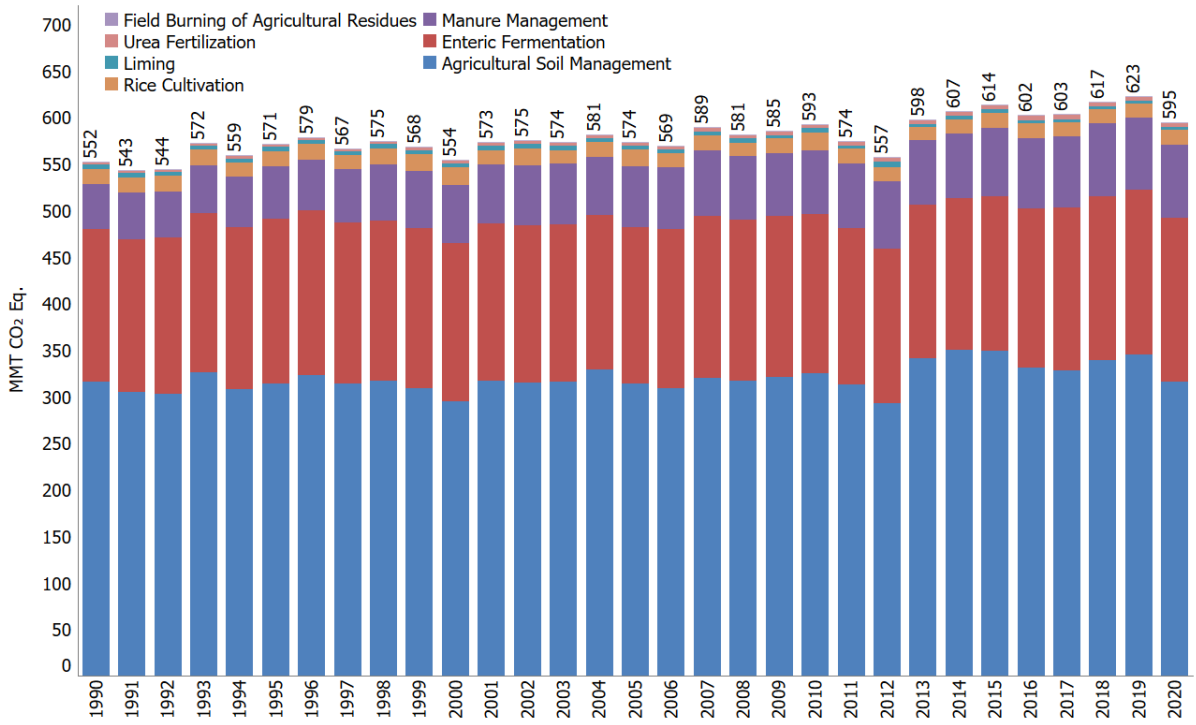


Table 2-7: Emissions from Agriculture (MMT CO_2 Eq.)

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CO_2	**7.1**	**7.9**	**7.8**	**8.0**	**7.3**	**7.6**	**7.7**
Urea Fertilization	2.4	3.5	4.7	4.9	5.0	5.1	5.3
Liming	4.7	4.3	3.1	3.1	2.2	2.4	2.4
CH_4	**214.7**	**235.5**	**244.7**	**247.8**	**251.1**	**250.3**	**250.9**
Enteric Fermentation	163.5	168.0	171.3	174.9	175.7	176.1	175.2
Manure Management	34.8	49.0	57.1	57.5	59.4	58.7	59.6
Rice Cultivation	16.0	18.0	15.8	14.9	15.6	15.1	15.7
Field Burning of Agricultural Residues	0.4	0.4	0.4	0.4	0.4	0.4	0.4
N_2O	**330.1**	**330.3**	**349.4**	**347.5**	**358.4**	**365.0**	**336.1**
Agricultural Soil Management	316.0	313.8	330.8	328.3	338.9	345.3	316.2
Manure Management	13.9	16.3	18.4	19.0	19.3	19.5	19.7
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	**551.9**	**573.6**	**601.9**	**603.2**	**616.7**	**622.9**	**594.7**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Agriculture source categories (Figure 2-9) over the thirty-one-year period from 1990 through 2020 included the following:

- Agricultural soils are the largest anthropogenic source of N_2O emissions in the United States, accounting for 74.2 percent of N_2O emissions in 2020 and 5.3 percent of total emissions in the United States in 2020. Estimated emissions from this source in 2020 were 316.2 MMT CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2020, although overall emissions were only 0.2 MMT CO_2 Eq. or 0.1 percent higher in 2020 than in 1990. Year-to-year fluctuations are largely a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.
- Enteric fermentation is the largest anthropogenic source of CH_4 emissions in the United States. In 2020, enteric fermentation CH_4 emissions were 26.9 percent of total CH_4 emissions (175.2 MMT CO_2 Eq.), which represents an increase of 11.7 MMT CO_2 Eq. (7.2 percent) since 1990. This increase in emissions from 1990 to 2020 in enteric fermentation generally follows the increasing trends in cattle populations. For example, from 1990 to 1995, emissions increased and then generally decreased from 1996 to 2004, mainly due to fluctuations in beef cattle populations and increased digestibility of feed for feedlot cattle. Emissions increased from 2005 to 2007, as both dairy and beef populations increased. Research indicates that the feed digestibility of dairy cow diets decreased during this period. Emissions decreased again from 2008 to 2014 as beef cattle populations again decreased. Emissions increased from 2014 to 2020, consistent with an increase in beef cattle population over those same years.
- Manure management emissions increased 62.5 percent between 1990 and 2020. This encompassed an increase of 71.0 percent for CH_4, from 34.8 MMT CO_2 Eq. in 1990 to 59.6 MMT CO_2 Eq. in 2020; and an increase of 41.2 percent for N_2O, from 13.9 MMT CO_2 Eq. in 1990 to 19.7 MMT CO_2 Eq. in 2020. The majority of the increase observed in CH_4 resulted from swine and dairy cattle manure, where emissions increased 44.2 and 122.0 percent, respectively, from 1990 to 2020. From 2019 to 2020, there was a 0.5 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.
- Liming and urea fertilization are the only sources of CO_2 emissions reported in the Agriculture sector. All other CO_2 emissions and removals are characterized in the LULUCF sector. Estimated emissions from these sources were 2.4 and 5.3 MMT CO_2 Eq., respectively. Liming emissions decreased by 1.3 percent relative to 2019 and decreased 2.3 MMT CO_2 Eq. or 49.0 percent relative to 1990, while urea fertilization emissions increased by 2.6 percent relative to 2019 and 2.9 MMT CO_2 Eq. or 118.3 percent relative to 1990.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also influence the carbon (C) stock fluxes on these lands and cause emissions of CH_4 and N_2O. Overall, managed land is a net sink for CO_2 (C sequestration) in the United States. The primary driver of fluxes on managed lands is from management of forest lands, but also includes trees in settlements (i.e., urban areas), afforestation, conversion of forest lands to settlements and croplands, the management of croplands and grasslands, flooded lands, and the landfilling of yard trimmings and food scraps. The main drivers for net forest sequestration include net forest growth, increasing forest area, and a net accumulation of C stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements,* is driven primarily by C stock gains in urban forests (i.e., Settlement Trees) through net tree growth and increased urban area, as well as long-term accumulation of C in landfills from additions of yard trimmings and food scraps.

The LULUCF sector in 2020 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 812.2 MMT CO_2 Eq. (Table 2-8).[3] This represents an offset of 13.6 percent of total (i.e., gross) greenhouse gas emissions in 2020. Emissions of CH_4 and N_2O from LULUCF activities in 2020 were 53.2 MMT CO_2 Eq. and represent 0.9 percent of total greenhouse gas emissions.[4] Between 1990 and 2020, total net C sequestration in the LULUCF sector decreased by 9.0 percent, primarily due to a decrease in the rate of net C accumulation in forests and *Cropland Remaining Cropland*, as well as an increase in CO_2 emissions from Land Converted to Settlements.

Flooded Land Remaining Flooded Land was the largest source of CH_4 emissions from LULUCF in 2020, totaling 19.9 MMT CO_2 Eq. (797 kt of CH_4). Forest fires were the second largest source of CH_4 emissions from LULUCF in 2020, totaling 13.6 MMT CO_2 Eq. (545 kt of CH_4). *Coastal Wetlands Remaining Coastal Wetlands* resulted in CH_4 emissions of 3.8 MMT CO_2 Eq. (154 kt of CH_4). Grassland fires resulted in CH_4 emissions of 0.3 MMT CO_2 Eq. (12 kt of CH_4). Land Converted to Wetlands, Drained Organic Soils, and Peatlands Remaining Peatlands resulted in CH_4 emissions of less than 0.05 MMT CO_2 Eq. each.

Forest fires were the largest source of N_2O emissions from LULUCF in 2020, totaling 11.7 MMT CO_2 Eq. (39 kt of N_2O). Nitrous oxide emissions from fertilizer application to settlement soils in 2020 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). Additionally, the application of synthetic fertilizers to forest soils in 2020 resulted in N_2O emissions of 0.5 MMT CO_2 Eq. (2 kt of N_2O). Grassland fires resulted in N_2O emissions of 0.3 MMT CO_2 Eq. (1 kt of N_2O). *Coastal Wetlands Remaining Coastal Wetlands* and Drained Organic Soils resulted in N_2O emissions of 0.2 MMT CO_2 Eq. each (0.5 kt of N_2O). Peatlands Remaining Peatlands resulted in N_2O emissions of less than 0.05 MMT CO_2 Eq. Figure 2-10 and Table 2-8 along with CH_4 and N_2O emissions (purple) for LULUCF source categories.

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

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

Figure 2-10: Trends in Emissions and Removals (Net CO_2 Flux) from Land Use, Land-Use Change, and Forestry

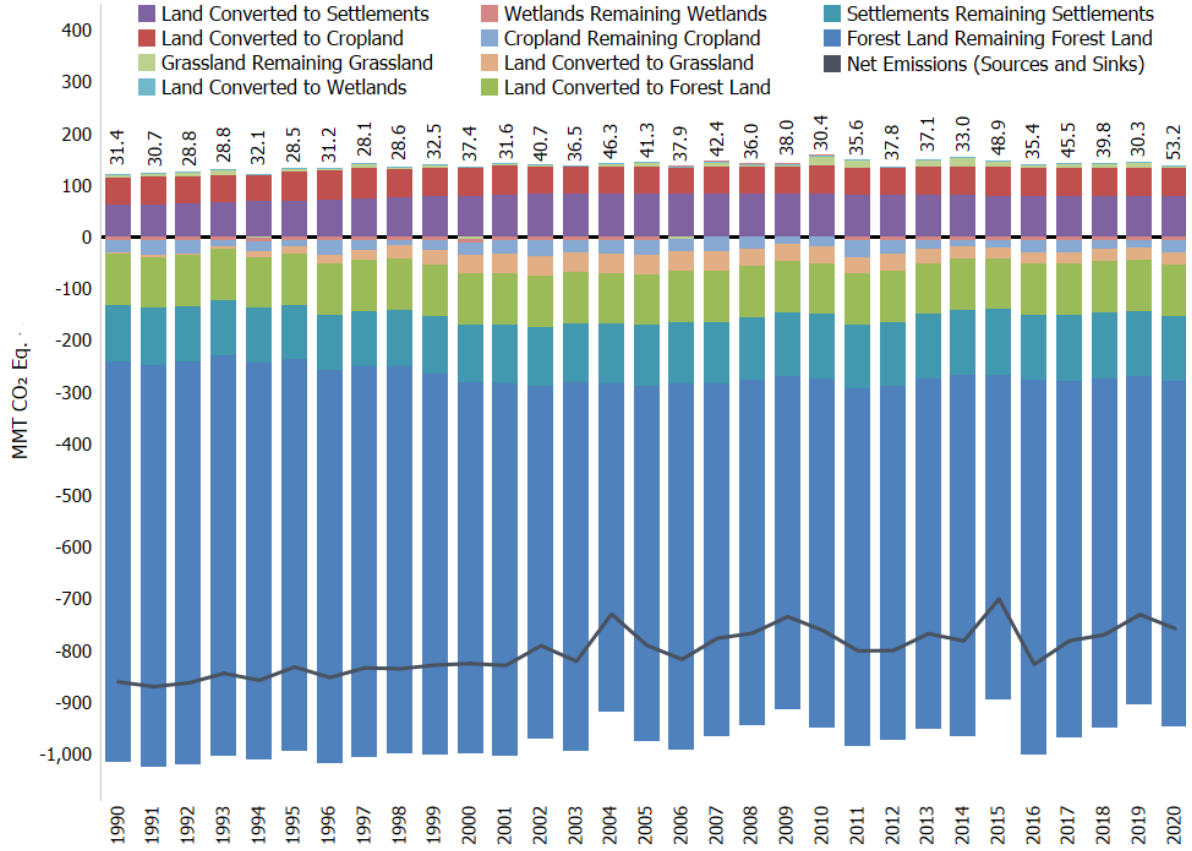


Table 2-8: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 Eq.)

Land-Use Category	1990	2005	2016	2017	2018	2019	2020
Forest Land Remaining Forest Land	**(769.7)**	**(674.0)**	**(717.3)**	**(670.1)**	**(664.6)**	**(631.8)**	**(642.2)**
Changes in Forest Carbon Stocks[a]	(774.0)	(687.3)	(725.6)	(688.3)	(677.1)	(634.8)	(668.1)
Non-CO_2 Emissions from Forest Fires[b]	4.1	12.8	7.8	17.7	11.9	2.5	25.3
N_2O Emissions from Forest Soils[c]	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Non-CO_2 Emissions from Drained Organic Soils[d]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Land Converted to Forest Land	**(98.6)**	**(99.1)**	**(99.5)**	**(99.5)**	**(99.5)**	**(99.5)**	**(99.5)**
Changes in Forest Carbon Stocks[e]	(98.6)	(99.1)	(99.5)	(99.5)	(99.5)	(99.5)	(99.5)
Cropland Remaining Cropland	**(23.2)**	**(29.0)**	**(22.7)**	**(22.3)**	**(16.6)**	**(14.5)**	**(23.3)**
Changes in Mineral and Organic Soil Carbon Stocks	(23.2)	(29.0)	(22.7)	(22.3)	(16.6)	(14.5)	(23.3)
Land Converted to Cropland	**51.8**	**52.0**	**54.1**	**54.3**	**54.0**	**53.9**	**54.4**
Changes in all Ecosystem Carbon Stocks[f]	51.8	52.0	54.1	54.3	54.0	53.9	54.4
Grassland Remaining Grassland	**7.1**	**9.4**	**8.6**	**9.9**	**10.3**	**13.1**	**5.1**
Changes in Mineral and Organic Soil Carbon Stocks	6.9	8.7	8.0	9.3	9.7	12.4	4.5
Non-CO_2 Emissions from Grassland Fires[g]	0.2	0.7	0.6	0.6	0.6	0.6	0.6
Land Converted to Grassland	**(3.1)**	**(37.0)**	**(22.6)**	**(22.7)**	**(22.4)**	**(21.5)**	**(24.1)**
Changes in all Ecosystem Carbon Stocks[f]	(3.1)	(37.0)	(22.6)	(22.7)	(22.4)	(21.5)	(24.1)

Wetlands Remaining Wetlands	**14.7**	**17.2**	**15.8**	**15.9**	**15.9**	**15.9**	**15.8**
Changes in Organic Soil Carbon Stocks in Peatlands	1.1	1.1	0.7	0.8	0.8	0.8	0.7
Non-CO_2 Emissions from Peatlands Remaining Peatlands	+	+	+	+	+	+	+
Changes in Biomass, DOM, and Soil Carbon Stocks in Coastal Wetlands	(8.5)	(7.6)	(8.8)	(8.8)	(8.8)	(8.8)	(8.8)
CH_4 Emissions from Coastal Wetlands Remaining Coastal Wetlands	3.7	3.8	3.8	3.8	3.8	3.8	3.8
N_2O Emissions from Coastal Wetlands Remaining Coastal Wetlands	0.1	0.2	0.1	0.1	0.2	0.2	0.2
CH_4 Emissions from Flooded Land Remaining Flooded Land	18.2	19.8	19.9	19.9	19.9	19.9	19.9
Land Converted to Wetlands	**7.2**	**1.3**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Changes in Biomass, DOM, and Soil Carbon Stocks in Land Converted to Coastal Wetlands	0.5	0.5	(+)	(+)	(+)	(+)	(+)
CH_4 Emissions from Land Converted to Coastal Wetlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Changes in Land Converted to Flooded Land	3.9	0.3	0.3	0.3	0.3	0.3	0.3
CH_4 Emissions from Land Converted to Flooded Land	2.6	0.2	0.2	0.2	0.2	0.2	0.2
Settlements Remaining Settlements	**(107.6)**	**(113.5)**	**(121.5)**	**(125.3)**	**(124.9)**	**(124.5)**	**(123.7)**
Changes in Organic Soil Carbon Stocks	11.3	12.2	16.0	16.0	15.9	15.9	15.9
Changes in Settlement Tree Carbon Stocks	(96.4)	(117.4)	(129.8)	(129.8)	(129.8)	(129.8)	(129.8)
N_2O Emissions from Settlement Soils[h]	2.0	3.1	2.2	2.3	2.4	2.4	2.5
Changes in Yard Trimming and Food Scrap Carbon Stocks in Landfills	(24.5)	(11.4)	(10.0)	(13.8)	(13.4)	(13.1)	(12.2)
Land Converted to Settlements	**60.8**	**82.8**	**77.8**	**77.9**	**78.0**	**77.9**	**77.9**
Changes in all Ecosystem Carbon Stocks[f]	60.8	82.8	77.8	77.9	78.0	77.9	77.9
LULUCF Emissions[i]	**31.4**	**41.3**	**35.4**	**45.5**	**39.8**	**30.3**	**53.2**
CH_4	27.2	30.9	28.3	34.0	30.7	25.5	38.1
N_2O	4.2	10.5	7.1	11.5	9.1	4.8	15.2
LULUCF Carbon Stock Change[j]	**(892.0)**	**(831.1)**	**(862.0)**	**(826.7)**	**(809.0)**	**(760.8)**	**(812.2)**
LULUCF Sector Net Total[k]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**

+ Absolute value does not exceed 0.05 MMT CO_2 Eq.

[a] Includes the net changes to carbon stocks stored in all forest ecosystem pools (estimates include C stock changes from drained organic soils from both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*.) and harvested wood products.

[b] Estimates include emissions from fires on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land.*

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

[d] Estimates include CH_4 and N_2O emissions from drained organic soils on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land.* Carbon stock changes from drained organic soils are included with the *Forest Land Remaining Forest Land* forest ecosystem pools.

[e] Includes the net changes to carbon stocks stored in all forest ecosystem pools.

[f] Includes changes in mineral and organic soil carbon stocks for all land use conversions to cropland, grassland, and settlements. Also includes aboveground/belowground biomass, dead wood, and litter carbon stock changes for conversion of forest land to cropland, grassland, and settlements.

[g] Estimates include CH_4 and N_2O emissions from fires on both Grassland Remaining Grassland and *Land Converted to Grassland.*

[h] Estimates include N_2O emissions from N fertilizer additions on both *Settlements Remaining Settlements* and Land Converted to Settlements because it is not possible to separate the activity data at this time.

[i] LULUCF Carbon Stock Change includes any C stock gains and losses from all land use and land use conversion categories.

[j] LULUCF emissions include the CH_4 and N_2O emissions reported for Peatlands Remaining Peatlands, *F*orest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from Flooded Land

Remaining Flooded Land, and Land Converted to Flooded Land, and *Land Converted to Coastal Wetlands*; and N_2O emissions from Forest Soils and Settlement Soils.

[k] The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes in units of MMT CO_2 Eq.

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

Other significant trends from 1990 to 2020 in emissions from LULUCF categories (Figure 2-10) over the thirty-one-year period included the following:

- Annual carbon (C) sequestration by forest land (i.e., annual C stock accumulation in the five ecosystem C pools and harvested wood products for *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*) has decreased by 12.0 percent since 1990. This is primarily due to decreased C stock gains in *Land Converted to Forest Land* and the harvested wood products pools within *Forest Land Remaining Forest Land*.
- Annual C sequestration from *Settlements Remaining Settlements* (which includes organic soils, settlement trees, and landfilled yard trimmings and food scraps) has increased by 15.1 percent over the period from 1990 to 2020. This is primarily due to an increase in urbanized land area in the United States with trees growing on it.
- Annual emissions from Land Converted to Settlements increased by 28.1 percent from 1990 to 2020 due primarily to C stock losses from Forest Land Converted to Settlements and mineral soils C stocks from Grassland Converted to Settlements.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-11 and Table 2-9). In 2020, landfills were the third-largest source of U.S. anthropogenic CH_4 emissions, generating 109.3 MMT CO_2 Eq. and accounting for 16.8 percent of total U.S. CH_4 emissions.[5] Additionally, wastewater treatment generates emissions of 41.8 MMT CO_2 Eq. and accounts for 26.9 percent of waste emissions, 2.8 percent of U.S. CH_4 emissions, and 5.5 percent of U.S. N_2O emissions. Emissions of CH_4 and N_2O from composting are also accounted for in this chapter, generating emissions of 2.3 MMT CO_2 Eq. and 2.0 MMT CO_2 Eq., respectively. Anaerobic digestion at biogas facilities generated CH_4 emissions of 0.2 MMT CO_2 Eq., accounting for 0.1 percent of emissions from the Waste sector. Overall, emission sources accounted for in the Waste chapter generated 155.6 MMT CO_2 Eq., or 2.6 percent of total U.S. greenhouse gas emissions in 2020.

[5] 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: Trends in Waste Sector Greenhouse Gas Sources

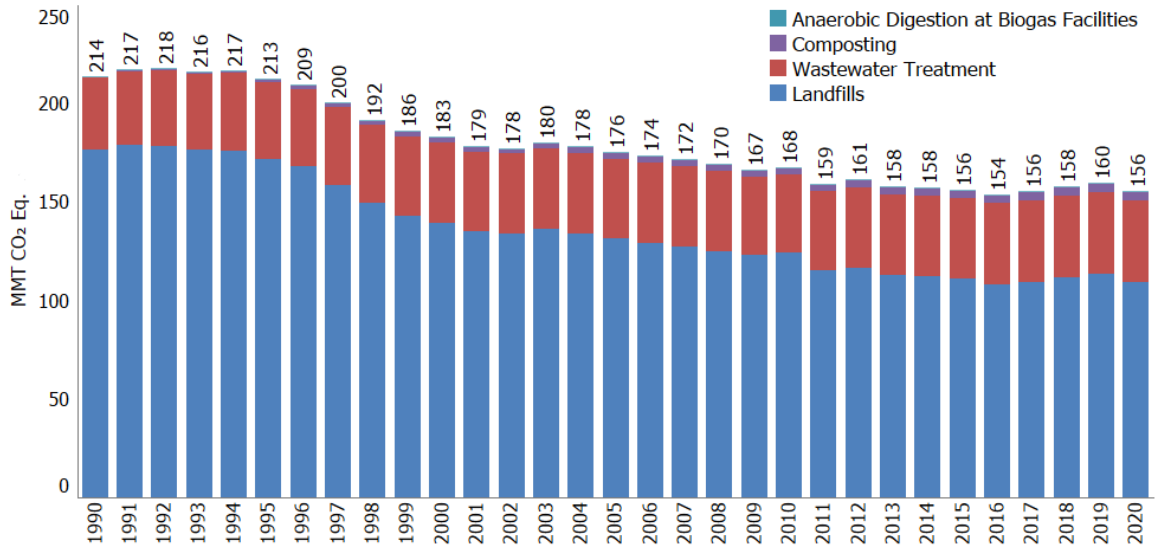


Table 2-9: Emissions from Waste (MMT CO_2 Eq.)

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CH_4	**197.3**	**153.6**	**129.1**	**130.3**	**132.4**	**134.1**	**130.0**
Landfills	176.6	131.5	107.9	109.2	111.7	113.6	109.3
Wastewater Treatment	20.3	20.1	18.7	18.5	18.3	18.1	18.3
Composting	0.4	1.9	2.3	2.5	2.3	2.3	2.3
Anaerobic Digestion at Biogas Facilities	+	+	0.2	0.2	0.2	0.2	0.2
N_2O	**16.9**	**22.0**	**24.8**	**25.4**	**25.5**	**25.4**	**25.6**
Wastewater Treatment	16.6	20.3	22.8	23.2	23.5	23.4	23.5
Composting	0.3	1.7	2.0	2.2	2.0	2.0	2.0
Total	**214.2**	**175.6**	**153.9**	**155.7**	**157.9**	**159.6**	**155.6**

+ Does not exceed 0.05 MMT CO_2 Eq.

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from waste source categories (Figure 2-11) over the thirty-one-year period from 1990 through 2020 included the following:

- Net CH_4 emissions from landfills decreased by 67.2 MMT CO_2 Eq. (38.1 percent), with small increases occurring in interim years. This downward trend in emissions coincided with increased landfill gas collection and control systems, and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in municipal solid waste (MSW) landfills over the time series.
- CH_4 and N_2O emissions from wastewater treatment decreased by 2.0 MMT CO_2 Eq. (10.0 percent) and increased by 6.9 MMT CO_2 Eq. (41.8 percent), respectively. Methane emissions from domestic wastewater treatment have decreased since 1999 due to decreasing percentages of wastewater being treated in anaerobic systems, including reduced use of on-site septic systems and central anaerobic treatment systems. Nitrous oxide emissions from wastewater treatment processes gradually increased across the time series as a result of increasing U.S. population and protein consumption.
- Combined CH_4 and N_2O emissions from composting have generally increased 3.6 MMT CO_2 Eq. since 1990, from 0.7 MMT CO_2 Eq. to 4.3 MMT CO_2 Eq. in 2020, which represents more than a six-fold increase over the time series. The growth in composting since the 1990s is attributable to primarily four factors: (1) the enactment of legislation by state and local governments that discouraged the disposal of yard trimmings

and food waste in landfills; (2) yard trimming collection and yard trimming drop off sites provided by local solid waste management districts; (3) an increased awareness of the environmental benefits of composting; and (4) loans or grant programs to establish or expand composting infrastructure.

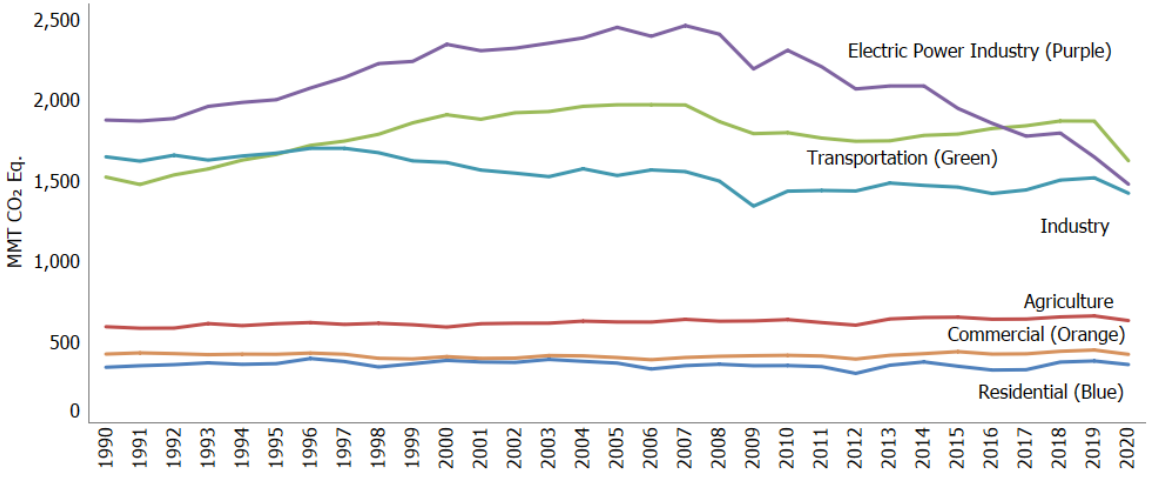
2.2 Emissions by Economic Sector

Throughout this report, emission estimates are grouped into five sectors (i.e., chapters) defined by the IPCC and detailed above: Energy, IPPU, Agriculture, LULUCF, and Waste. It is also useful to characterize emissions according to commonly used economic sector categories: residential, commercial, industry, transportation, electric power, and agriculture. Emissions from U.S. Territories are reported as their own end-use sector due to a lack of specific consumption data for the individual end-use sectors within U.S. Territories. See Box 2-1 for more information on how economic sectors are defined. For more information on trends in the Land Use, Land Use Change, and Forestry sector, see Section 2.1.

Using this categorization, transportation activities accounted for the largest portion (27.2 percent) of total U.S. greenhouse gas emissions in 2020. Emissions from electric power accounted for the second largest portion (24.8 percent), while emissions from industry accounted for the third largest portion (23.8 percent) of total U.S. greenhouse gas emissions in 2020. Emissions from industry have in general declined over the past decade due to a number of factors, including structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements.

The remaining 24.2 percent of U.S. greenhouse gas emissions were contributed by, in order of magnitude, the agriculture, commercial, and residential sectors, plus emissions from U.S. Territories. Activities related to agriculture accounted for roughly 10.6 percent of 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. An increasing amount of carbon is stored in agricultural soils each year, but this CO_2 sequestration is assigned to the LULUCF sector rather than the agriculture economic sector. The commercial and residential sectors accounted for roughly 7.1 percent and 6.1 percent of greenhouse gas emissions, respectively, and U.S. Territories accounted for 0.4 percent of emissions; emissions from these sectors primarily consisted of CO_2 emissions from fossil fuel combustion. Carbon dioxide was also emitted and sequestered (in the form of C) by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings, and changes in C stocks in coastal wetlands. Table 2-10 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-12 shows the trend in emissions by sector from 1990 to 2020.

Figure 2-12: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors



Note: Emissions and removals from Land Use, Land Use Change, and Forestry are excluded from figure above. Excludes U.S. Territories.

Table 2-10: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq. and Percent of Total in 2020)

Sector/Source	1990	2005	2016	2017	2018	2019	2020	Percent[a]
Transportation	**1,526.4**	**1,975.5**	**1,828.0**	**1,845.2**	**1,874.7**	**1,874.3**	**1,627.6**	**27.2%**
CO_2 from Fossil Fuel Combustion	1,468.9	1,858.6	1,757.6	1,780.0	1,812.8	1,813.8	1,572.0	26.3%
Substitution of Ozone Depleting Substances	+	69.3	43.3	40.1	38.5	36.7	35.0	0.6%
Mobile Combustion[b]	45.7	37.5	16.7	15.5	14.3	15.0	12.5	0.2%
Non-Energy Use of Fuels	11.8	10.2	10.4	9.6	9.2	8.8	8.0	0.1%
Electric Power Industry	**1,880.5**	**2,456.7**	**1,860.5**	**1,780.6**	**1,799.8**	**1,651.0**	**1,482.2**	**24.8%**
CO_2 from Fossil Fuel Combustion	1,820.0	2,400.1	1,808.9	1,732.0	1,752.9	1,606.1	1,439.0	24.1%
Stationary Combustion[b]	20.9	30.9	27.4	25.9	25.6	22.3	21.0	0.4%
Incineration of Waste	13.4	13.7	14.8	13.6	13.8	13.4	13.5	0.2%
Other Process Uses of Carbonates	3.1	3.7	5.4	4.9	3.7	4.9	4.9	0.1%
Electrical Transmission and Distribution	23.2	8.4	4.1	4.2	3.8	4.2	3.8	0.1%
Industry	**1,652.4**	**1,536.2**	**1,424.4**	**1,446.7**	**1,507.6**	**1,521.7**	**1,426.2**	**23.8%**
CO_2 from Fossil Fuel Combustion	810.3	800.7	752.6	750.6	774.3	776.4	727.2	12.2%
Natural Gas Systems	227.4	202.5	195.0	197.7	204.2	210.9	200.3	3.3%
Non-Energy Use of Fuels	97.0	111.2	88.4	102.8	119.4	117.7	112.7	1.9%
Petroleum Systems	57.4	53.4	62.3	65.6	75.9	87.1	70.4	1.2%
Coal Mining	101.1	68.3	56.7	57.9	55.8	50.3	43.4	0.7%
Cement Production	33.5	46.2	39.4	40.3	39.0	40.9	40.7	0.7%
Iron and Steel Production	104.8	70.1	43.6	40.6	42.6	43.1	37.7	0.6%
Substitution of Ozone Depleting Substances	+	8.6	29.9	32.4	34.4	35.7	36.5	0.6%
Petrochemical Production	21.8	27.5	28.4	29.1	29.6	31.0	30.3	0.5%
Landfills (Industrial)	10.9	14.4	15.0	15.0	15.0	15.1	15.1	0.3%
Ammonia Production	13.0	9.2	10.2	11.1	12.2	12.3	12.7	0.2%
Lime Production	11.7	14.6	12.6	12.9	13.1	12.1	11.3	0.2%
Nitric Acid Production	12.1	11.3	10.1	9.3	9.6	10.0	9.3	0.2%
Adipic Acid Production	15.2	7.1	7.1	7.5	10.5	5.3	8.3	0.1%
Wastewater Treatment	6.0	6.5	6.6	6.7	6.8	6.9	6.9	0.1%
Abandoned Oil and Gas Wells	6.5	6.8	6.9	6.9	6.9	7.0	6.9	0.1%
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	5.3	5.2	6.0	6.0	6.0	0.1%
Abandoned Underground Coal Mines	7.2	6.6	6.7	6.4	6.2	5.9	5.8	0.1%
Mobile Combustion[b]	3.9	6.1	5.6	5.8	6.0	6.1	5.7	0.1%
Carbon Dioxide Consumption	1.5	1.4	4.6	4.6	4.1	4.9	5.0	0.1%
Other Process Uses of Carbonates	3.1	3.7	5.4	4.9	3.7	4.9	4.9	0.1%
Electronics Industry	3.6	4.8	5.0	4.9	5.1	4.7	4.7	0.1%
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.1%
Stationary Combustion[b]	4.9	4.7	4.2	4.1	4.0	4.0	3.7	+%
Aluminum Production	28.3	7.6	2.7	2.3	3.1	3.6	3.4	0.1%
HCFC-22 Production	46.1	20.0	2.8	5.2	3.3	3.7	2.1	0.1%
Glass Production	2.3	2.4	2.1	2.0	2.0	1.9	1.9	+%
Soda Ash Production	1.4	1.7	1.7	1.8	1.7	1.8	1.5	+%
Ferroalloy Production	2.2	1.4	1.8	2.0	2.1	1.6	1.4	+%
Titanium Dioxide Production	1.2	1.8	1.7	1.7	1.5	1.5	1.3	+%

Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	1.7	1.5	1.4	1.4	1.2	+%
Zinc Production	0.6	1.0	0.8	0.9	1.0	1.0	1.0	+%
Phosphoric Acid Production	1.5	1.3	1.0	1.0	0.9	0.9	0.9	+%
Magnesium Production and Processing	5.3	2.7	1.2	1.1	1.1	0.9	0.9	+%
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5	+%
Carbide Production and Consumption	0.3	0.2	0.2	0.2	0.2	0.2	0.2	+%
Agriculture	**596.8**	**626.3**	**643.4**	**644.4**	**657.9**	**663.9**	**635.1**	**10.6%**
N_2O from Agricultural Soil Management	316.0	313.8	330.8	328.3	338.9	345.3	316.2	5.3%
Enteric Fermentation	163.5	168.0	171.3	174.9	175.7	176.1	175.2	2.9%
Manure Management	48.8	65.3	75.5	76.5	78.7	78.2	79.2	1.3%
CO_2 from Fossil Fuel Combustion	43.4	50.8	40.2	39.8	39.8	39.7	39.1	0.7%
Rice Cultivation	16.0	18.0	15.8	14.9	15.6	15.1	15.7	0.3%
Urea Fertilization	2.4	3.5	4.7	4.9	5.0	5.1	5.3	0.1%
Liming	4.7	4.3	3.1	3.1	2.2	2.4	2.4	+%
Mobile Combustion[b]	1.5	1.8	1.4	1.4	1.4	1.4	1.3	+%
Field Burning of Agricultural Residues	0.5	0.6	0.6	0.6	0.6	0.6	0.6	+%
Stationary Combustion[b]	+	+	+	+	+	+	+	+%
Commercial	**427.1**	**405.4**	**426.9**	**428.5**	**444.2**	**452.1**	**425.3**	**7.1%**
CO_2 from Fossil Fuel Combustion	228.3	227.1	231.5	232.0	245.8	250.7	226.8	3.8%
Landfills (Municipal)	165.7	117.2	93.0	94.2	96.7	98.6	94.2	1.6%
Substitution of Ozone Depleting Substances	+	22.1	61.5	61.0	60.8	62.3	63.5	1.1%
Wastewater Treatment	30.9	34.0	34.9	35.0	35.0	34.5	34.8	0.6%
Composting	0.7	3.5	4.3	4.6	4.3	4.3	4.3	0.1%
Stationary Combustion[b]	1.5	1.4	1.5	1.5	1.6	1.6	1.5	+%
Anaerobic Digestion at Biogas Facilities	+	+	0.2	0.2	0.2	0.2	0.2	+%
Residential	**345.1**	**371.0**	**327.8**	**329.9**	**377.4**	**384.2**	**362.0**	**6.1%**
CO_2 from Fossil Fuel Combustion	338.6	358.9	292.8	293.4	338.2	341.4	315.8	5.3%
Substitution of Ozone Depleting Substances	0.2	7.2	30.4	31.9	33.7	37.1	41.2	0.7%
Stationary Combustion[b]	6.3	4.9	4.7	4.5	5.5	5.7	4.9	0.1%
U.S. Territories	**25.1**	**63.7**	**26.8**	**25.8**	**25.8**	**24.6**	**23.0**	**0.4%**
CO_2 from Fossil Fuel Combustion	21.7	55.9	26.0	25.5	25.5	24.3	22.7	0.4%
Non-Energy Use of Fuels	3.4	7.6	0.7	0.2	0.2	0.2	0.2	+%
Stationary Combustion[b]	0.1	0.2	0.1	0.1	0.1	0.1	0.1	+%
Total Gross Emissions (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**	**100.0%**
LULUCF Sector Net Total[c]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**	**(12.7%)**
Net Emissions (Sources and Sinks)	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**	**87.3%**

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

[a] Percent of total (gross) emissions excluding emissions from LULUCF for 2020.

[b] Includes CH_4 and N_2O emissions from fuel combustion.

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

Notes: Total emissions presented without LULUCF. Total net emissions presented with LULUCF. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

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

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

The *Electric Power* economic sector includes CO_2, CH_4 and N_2O emissions from the combustion of fossil fuels that are included in the EIA electric power sector. Carbon dioxide, CH_4, and N_2O emissions from waste incineration are included in the Electric Power economic sector, as the majority of municipal solid waste is combusted in plants that produce electricity. The Electric Power economic sector also includes SF_6 from Electrical Transmission and Distribution, and a portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in electric power plants).

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

The *Industry* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA industrial fuel-consuming sector, minus the agricultural use of fuel explained below. The CH_4 and N_2O emissions from stationary and mobile combustion are also apportioned to the Industry economic sector based on the EIA industrial fuel-consuming sector, minus emissions apportioned to the Agriculture economic sector. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector. Finally, CH_4 emissions from industrial landfills and CH_4 and N_2O from industrial wastewater treatment are included in the Industry economic sector.

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

The *Agriculture* economic sector includes CO_2 emissions from the combustion of fossil fuels that are based on supplementary sources of agriculture fuel use data, because EIA includes agriculture equipment in the industrial fuel-consuming sector. Agriculture fuel use estimates are obtained from U.S. Department of Agriculture survey data, in combination with EIA Fuel Oil and Kerosene Sales (FOKS) data (EIA 1991 through 2021). Agricultural operations are based on annual energy expense data from the Agricultural Resource Management Survey (ARMS) conducted by the National Agricultural Statistics Service (NASS) of the USDA. NASS collects information on farm production expenditures including expenditures on diesel fuel, gasoline, LP gas, natural gas, and electricity use on the farm with the annual ARMS. A USDA publication (USDA/NASS 2020) shows national totals, as well as select States and ARMS production regions. These supplementary data are subtracted from the industrial fuel use reported by EIA to obtain agriculture fuel use. CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion, are then apportioned to the Agriculture economic sector based on agricultural fuel use.

The other IPCC Agriculture emission source categories apportioned to the Agriculture economic sector include

N_2O emissions from Agricultural Soils, CH_4 from Enteric Fermentation, CH_4 and N_2O from Manure Management, CH_4 from Rice Cultivation, CO_2 emissions from Liming and Urea Application, and CH_4 and N_2O from Field Burning of Agricultural Residues.

The *Residential* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA residential fuel-consuming sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA residential fuel-consuming sector. Substitution of Ozone Depleting Substances are apportioned to the Residential economic sector based on emissions from residential air-conditioning systems. Nitrous oxide emissions from the application of fertilizers to developed land (termed "settlements" by the IPCC) are also included in the Residential economic sector.

The *Commercial* economic sector includes CO_2 emissions from the combustion of fossil fuels that are included in the EIA commercial fuel-consuming sector. Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to the Commercial economic sector based on the EIA commercial fuel-consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned to the Commercial economic sector based on emissions from commercial refrigeration/air-conditioning systems. Public works sources, including direct CH_4 from municipal landfills, CH_4 from anaerobic digestion at biogas facilities, CH_4 and N_2O from domestic wastewater treatment, and composting, are also included in the Commercial economic sector.

Emissions with Electricity Distributed to Economic Sectors

It is also useful to view greenhouse gas emissions from economic sectors with emissions related to electric power distributed into end-use categories (i.e., emissions from electric power are allocated to the economic sectors in which the electricity is used).

The generation, transmission, and distribution of electricity accounted for 24.8 percent of total U.S. greenhouse gas emissions in 2020. Electric power-related emissions decreased by 21.2 percent since 1990 and by 10.2 percent from 2019 to 2020, due to the impacts of the COVID-19 pandemic in 2020 compared to 2019 and continued fuel switching in the electric power sector. Between 2019 to 2020, the consumption of natural gas for electric power generation increased by 2.9, while the consumption of coal and petroleum decreased by 19.2 and 2.2 percent, respectively, reflecting a continued shift from coal to natural gas for electricity generation.

From 2019 to 2020, electricity sales to the residential end-use sector increased by 1.7 percent. Alternatively, electricity sales to the commercial end-use and industrial sectors decreased by 5.4 percent and 4.3 percent, respectively. Overall, from 2019 to 2020, the amount of electricity retail sales (in kWh) decreased by 2.5 percent. Table 2-11 provides a detailed summary of emissions from electric power-related activities.

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

Gas/Fuel Type or Source	1990	2005	2016	2017	2018	2019	2020
CO_2	**1,836.0**	**2,417.1**	**1,828.6**	**1,750.1**	**1,770.0**	**1,624.0**	**1,457.0**
Fossil Fuel Combustion	1,820.0	2,400.1	1,808.9	1,732.0	1,752.9	1,606.1	1,439.0
Coal	*1,546.5*	*1,982.8*	*1,242.0*	*1,207.1*	*1,152.9*	*973.5*	*788.2*
Natural Gas	*175.4*	*318.9*	*545.0*	*505.6*	*577.4*	*616.0*	*634.3*
Petroleum	*97.5*	*98.0*	*21.5*	*18.9*	*22.2*	*16.2*	*16.2*
Geothermal	*0.5*	*0.5*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	12.9	13.3	14.4	13.2	13.3	12.9	13.1
Other Process Uses of Carbonates	3.1	3.7	5.4	4.9	3.7	4.9	4.9
CH_4	**0.4**	**0.9**	**1.2**	**1.1**	**1.2**	**1.3**	**1.2**
Stationary Sources[a]	0.4	0.9	1.2	1.1	1.2	1.3	1.2
Incineration of Waste	+	+	+	+	+	+	+
N_2O	**21.0**	**30.4**	**26.6**	**25.2**	**24.8**	**21.5**	**20.1**
Stationary Sources[a]	20.5	30.1	26.2	24.8	24.4	21.1	19.7
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
SF_6	**23.2**	**8.3**	**4.1**	**4.2**	**3.8**	**4.2**	**3.8**
Electrical Transmission and Distribution	23.2	8.3	4.1	4.2	3.8	4.2	3.8
PFCs	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Electrical Transmission and Distribution	+	+	+	+	+	+	+
Total	**1,880.5**	**2,456.7**	**1,860.5**	**1,780.6**	**1,799.8**	**1,651.0**	**1,482.2**

+ Does not exceed 0.05 MMT CO_2 Eq.

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

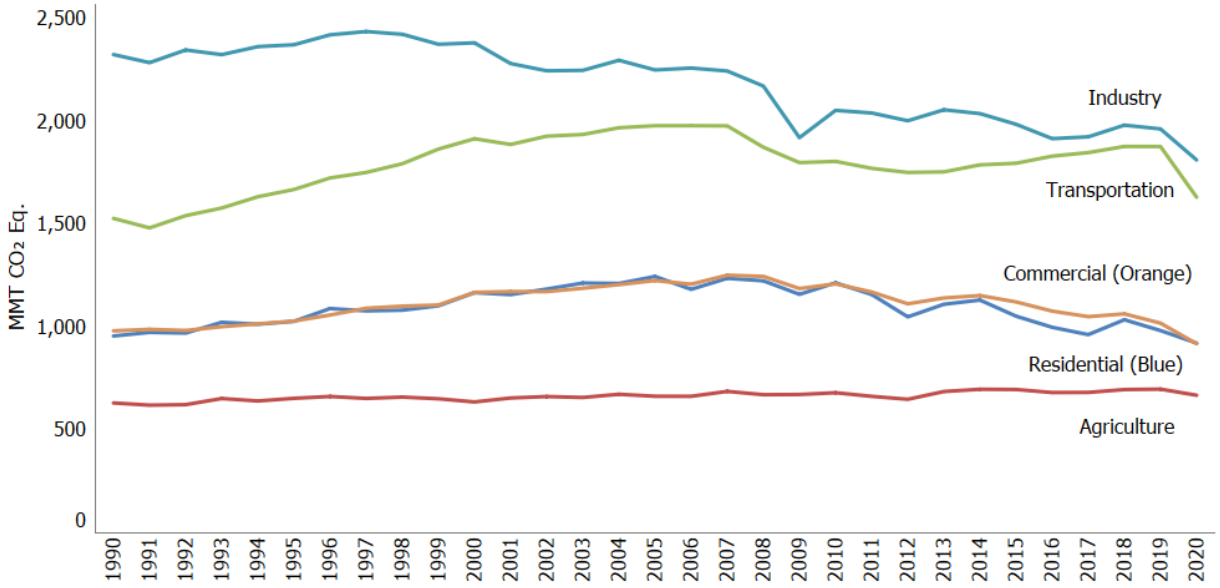
Note: Totals may not sum due to independent rounding.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electric power sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to each economic sector's share of retail sales of electricity (EIA 2020b; USDA/NASS 2020). These source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Incineration of Waste, Other Process Uses of Carbonates, and SF_6 from Electrical Transmission and Distribution Systems. Note that only 50 percent of the Other Process Uses of Carbonates emissions were associated with electric power and distributed as described; the remainder of Other Process Uses of Carbonates emissions were attributed to the industrial processes economic end-use sector.[6]

When emissions from electricity use are distributed among these economic end-use sectors, industrial activities account for the largest share of total U.S. greenhouse gas emissions (30.3 percent), followed closely by emissions from transportation (27.3 percent). Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included (both 15.4 percent). In all economic end-use sectors except agriculture, CO_2 accounts for more than 77.5 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels. Table 2-12 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electric power distributed to them. Figure 2-13 shows the trend in these emissions by sector from 1990 to 2020.

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

Figure 2-13: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors



Note: Emissions and removals from Land Use, Land-Use Change, and Forestry are excluded from figure above. Excludes U.S. Territories.

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 2020

Sector/Gas	1990	2005	2016	2017	2018	2019	2020	Percent[a]
Industry	**2,326.5**	**2,251.6**	**1,917.5**	**1,926.4**	**1,983.1**	**1,964.7**	**1,813.7**	**30.3%**
Direct Emissions	**1,652.4**	**1,536.2**	**1,424.4**	**1,446.7**	**1,507.6**	**1,521.7**	**1,426.2**	**23.8%**
CO_2	1,163.3	1,143.6	1,056.1	1,072.4	1,127.9	1,148.8	1,066.3	17.8%
CH_4	372.7	319.5	296.8	299.1	300.3	297.0	283.2	4.7%
N_2O	40.1	33.6	31.3	30.7	34.1	29.3	31.0	0.5%
HFCs, PFCs, SF_6 and NF_3	76.3	39.5	40.1	44.4	45.3	46.6	45.6	0.8%
Electricity-Related	**674.1**	**715.4**	**493.2**	**479.7**	**475.4**	**443.1**	**387.5**	**6.5%**
CO_2	658.1	703.8	484.7	471.5	467.6	435.8	380.9	6.4%
CH_4	0.2	0.3	0.3	0.3	0.3	0.3	0.3	+%
N_2O	7.5	8.9	7.1	6.8	6.6	5.8	5.3	0.1%
SF_6	8.3	2.4	1.1	1.1	1.0	1.1	1.0	+%
Transportation	**1,529.6**	**1,980.3**	**1,832.4**	**1,849.6**	**1,879.5**	**1,879.1**	**1,632.4**	**27.3%**
Direct Emissions	**1,526.4**	**1,975.5**	**1,828.0**	**1,845.2**	**1,874.7**	**1,874.3**	**1,627.6**	**27.2%**
CO_2	1,480.8	1,868.7	1,768.0	1,789.5	1,822.0	1,822.6	1,580.1	26.4%
CH_4	5.7	2.9	1.6	1.5	1.4	1.4	1.2	+%
N_2O	39.9	34.5	15.1	14.0	12.9	13.5	11.3	0.2%
HFCs[b]	+	69.3	43.3	40.1	38.5	36.7	35.0	0.6%
Electricity-Related	**3.1**	**4.8**	**4.3**	**4.4**	**4.8**	**4.9**	**4.8**	**0.1%**
CO_2	3.1	4.8	4.2	4.3	4.7	4.8	4.7	0.1%
CH_4	+	+	+	+	+	+	+	+%
N_2O	+	0.1	0.1	0.1	0.1	0.1	0.1	+%
SF_6	+	+	+	+	+	+	+	+%
Residential	**957.6**	**1,247.2**	**999.9**	**964.3**	**1,036.7**	**984.1**	**923.1**	**15.4%**
Direct Emissions	**345.1**	**371.0**	**327.8**	**329.9**	**377.4**	**384.2**	**362.0**	**6.1%**
CO_2	338.6	358.9	292.8	293.4	338.2	341.4	315.8	5.3%
CH_4	5.2	4.1	3.9	3.8	4.6	4.7	4.1	0.1%
N_2O	1.0	0.9	0.8	0.8	0.9	0.9	0.8	+%

SF_6	0.2	7.2	30.4	31.9	33.7	37.1	41.2	0.7%
Electricity-Related	**612.5**	**876.2**	**672.1**	**634.4**	**659.4**	**599.9**	**561.1**	**9.4%**
CO_2	598.0	862.1	660.6	623.6	648.4	590.1	551.6	9.2%
CH_4	0.1	0.3	0.4	0.4	0.4	0.5	0.5	+%
N_2O	6.8	10.9	9.6	9.0	9.1	7.8	7.6	0.1%
SF_6	7.5	3.0	1.5	1.5	1.4	1.5	1.4	+%
Commercial	**982.7**	**1,227.4**	**1,078.6**	**1,051.7**	**1,065.3**	**1,020.1**	**919.7**	**15.4%**
Direct Emissions	**427.1**	**405.4**	**426.9**	**428.5**	**444.2**	**452.1**	**425.3**	**7.1%**
CO_2	228.3	227.1	231.5	232.0	245.8	250.7	226.8	3.8%
CH_4	181.9	134.3	109.2	110.3	112.3	113.9	109.6	1.8%
N_2O	16.9	21.8	24.6	25.2	25.3	25.3	25.4	0.4%
HFCs	+	22.1	61.5	61.0	60.8	62.3	63.5	1.1%
Electricity-Related	**555.6**	**822.0**	**651.7**	**623.2**	**621.1**	**567.9**	**494.4**	**8.3%**
CO_2	542.5	808.7	640.6	612.6	610.8	558.6	486.0	8.1%
CH_4	0.1	0.3	0.4	0.4	0.4	0.4	0.4	+%
N_2O	6.2	10.2	9.3	8.8	8.6	7.4	6.7	0.1%
SF_6	6.8	2.8	1.4	1.5	1.3	1.5	1.3	+%
Agriculture	**631.9**	**664.6**	**682.6**	**683.2**	**697.1**	**699.1**	**669.5**	**11.2%**
Direct Emissions	**596.8**	**626.3**	**643.4**	**644.4**	**657.9**	**663.9**	**635.1**	**10.6%**
CO_2	50.5	58.7	47.9	47.8	47.1	47.2	46.7	0.8%
CH_4	214.8	235.7	244.8	247.9	251.2	250.5	251.0	4.2%
N_2O	331.5	331.9	350.7	348.7	359.6	366.2	337.3	5.6%
Electricity-Related	**35.2**	**38.3**	**39.2**	**38.8**	**39.2**	**35.2**	**34.4**	**0.6%**
CO_2	34.3	37.7	38.5	38.1	38.5	34.6	33.8	0.6%
CH_4	+	+	+	+	+	+	+	+%
N_2O	0.4	0.5	0.6	0.5	0.5	0.5	0.5	+%
SF_6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	+%
U.S. Territories	**25.1**	**63.7**	**26.8**	**25.8**	**25.8**	**24.6**	**23.0**	**0.4%**
Total Gross Emissions (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**	**100.0%**
LULUCF Sector Net Total[c]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**	**(12.7%)**
Net Emissions (Sources and Sinks)	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**	**87.3%**

Electricity-Related (Electricity)

+ 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 2020.

[b] Includes primarily HFC-134a.

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

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

Industry

The industry end-use sector includes CO_2 emissions from fossil fuel combustion from all manufacturing facilities, in aggregate, and with the distribution of electricity-related emissions, accounts for 30.3 percent of U.S. greenhouse gas emissions in 2020. This end-use sector also includes emissions that are produced as a byproduct of the non-energy-related industrial process activities. The variety of activities producing these non-energy-related emissions includes CH_4 emissions from petroleum and natural gas systems, fugitive CH_4 and CO_2 emissions from coal mining, byproduct CO_2 emissions from cement manufacture, and HFC, PFC, SF_6, and NF_3 byproduct emissions from the electronics industry, to name a few.

Since 1990, industrial sector emissions have declined by 22.0 percent. The decline has occurred both in direct emissions and indirect emissions associated with electricity use. Structural changes within the U.S. economy that led to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) have had a significant effect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 27.2 percent of U.S. greenhouse gas emissions in 2020. The largest sources of transportation greenhouse gas emissions in 2020 were passenger cars (37.8 percent); freight trucks (25.9 percent); light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (19.3 percent); commercial aircraft (5.6 percent); pipelines (3.5 percent); rail (2.1 percent); ships and boats (2.0 percent); and other aircraft (1.9 percent). These figures include direct CO_2, CH_4, and N_2O emissions from fossil fuel combustion used in transportation, indirect emissions from electricity use, 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.

From 1990 to 2020, total transportation emissions from fossil fuel combustion increased by approximately 4.8 percent. From 1990 to 2019, emissions increased by 20.9 percent, followed by a decline of 13.3 percent from 2019 to 2020. The increase in transportation emissions from 1990 to 2019 was due, in large part, to increased demand for travel. The number of VMT by light-duty motor vehicles (passenger cars and light-duty trucks) increased 47.5 percent from 1990 to 2019, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and periods of low fuel prices. The drop in transportation emissions from 2019 to 2020 was primarily the result of less travel caused by the COVID-19 pandemic. During this period, the number of VMT by light-duty motor vehicles decreased by 12.2 percent.

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 approximately 29.6 percent of new vehicle sales in 1990 to 48.0 percent in 2004. Starting in 2005, average new vehicle fuel economy began to increase while light-duty VMT grew only modestly for much of the period. Light-duty VMT grew by less than one percent or declined each year between 2005 and 2013,[7] then grew at a faster rate until 2016 (2.6 percent from 2014 to 2015, and 2.5 percent from 2015 to 2016). Since 2016, the rate of light-duty VMT growth has slowed to at or less than one percent each year. Average new vehicle fuel economy has increased almost every year since 2005, while light-duty truck market share decreased to 33.0 percent in 2009 and has since varied from year to year between 35.6 and 56.1 percent. Light-duty truck market share was about 56.1 percent of new vehicles in model year 2020 (EPA 2021a).

Table 2-13 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals. Historically, the majority of electricity use in the transportation sector was for rail transport. However, more recently there has been increased electricity use in on-road electric and plug-in hybrid vehicles. For a more detailed breakout of emissions by fuel type by vehicle see Table A-99 in Annex 3.

Almost all of the energy used 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 7.0 percent from 1990 to 2020.[8] This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 35.0 MMT CO_2 Eq. in 2020, led to an increase in overall greenhouse gas emissions from transportation activities of 6.7 percent.[9]

[7] VMT estimates are based on data from FHWA Highway Statistics Table VM-1 (FHWA 1996 through 2021). In 2007 and 2008 light-duty VMT decreased 3.9 percent and 2.3 percent, respectively. Note that the decline in light-duty VMT from 2006 to 2007 is due at least in part to a change in FHWA's methods for estimating VMT. In 2011, FHWA changed its methods for estimating VMT by vehicle class, which led to a shift in VMT and emissions among on-road vehicle classes in the 2007 to 2018 time period. In absence of these method changes, light-duty VMT growth between 2006 and 2007 would likely have been higher.

[8] See previous footnote.

[9] See previous footnote.

Figure 2-14: Trends in Transportation-Related Greenhouse Gas Emissions[10]

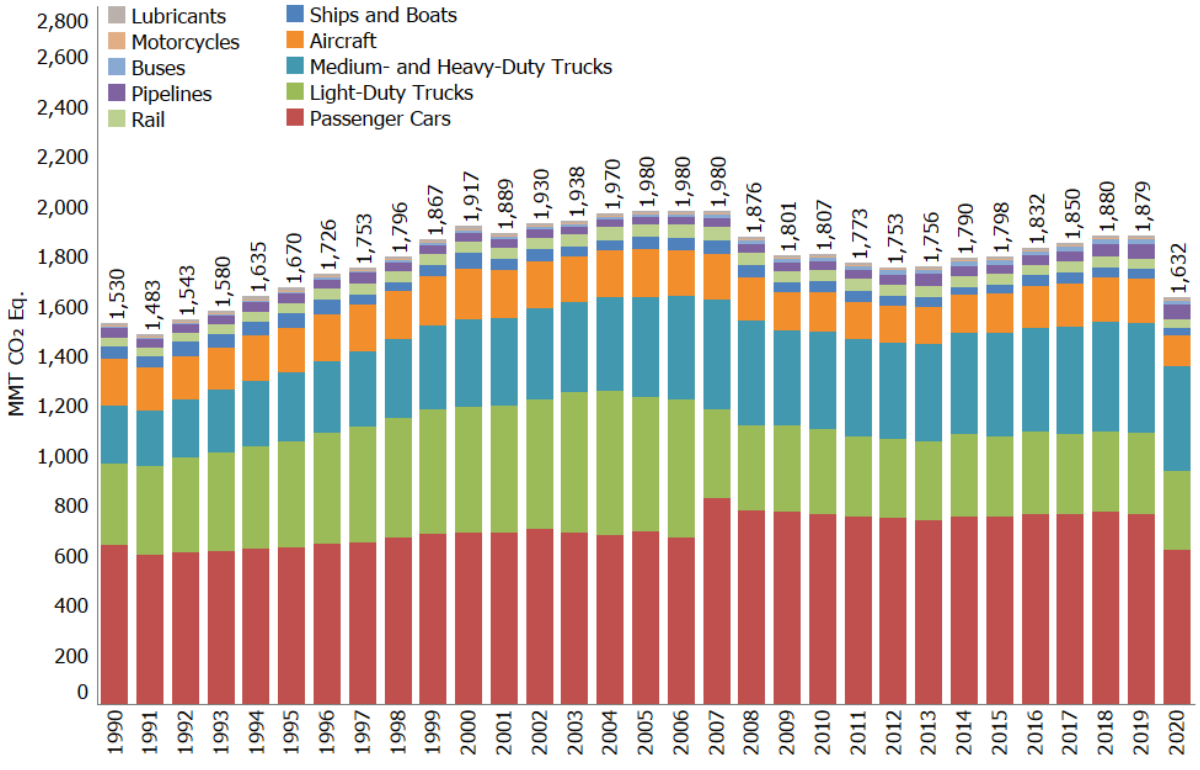


Table 2-13: Transportation-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Vehicle	1990	2005	2016	2017	2018	2019	2020
Passenger Cars	**639.6**	**691.7**	**763.2**	**760.6**	**770.2**	**763.1**	**617.7**
CO_2	612.2	641.4	742.4	742.5	754.2	748.0	605.0
CH_4	3.2	1.3	0.6	0.5	0.5	0.5	0.4
N_2O	24.1	17.3	7.1	6.1	5.1	5.3	3.9
HFCs	0.0	31.7	13.2	11.4	10.4	9.3	8.3
Light-Duty Trucks	**326.7**	**537.7**	**330.0**	**324.3**	**325.6**	**323.7**	**315.8**
CO_2	312.2	490.0	305.8	302.4	305.2	304.0	297.8
CH_4	1.7	0.8	0.2	0.2	0.2	0.2	0.2
N_2O	12.8	13.6	2.9	2.4	2.1	2.5	2.2
HFCs	0.0	33.3	21.1	19.2	18.1	16.9	15.6
Medium- and Heavy-Duty Trucks	**230.3**	**404.1**	**416.8**	**429.7**	**440.0**	**439.5**	**422.8**
CO_2	229.3	399.4	408.2	420.8	430.7	429.9	412.9
CH_4	0.3	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.7	1.2	2.9	3.1	3.3	3.4	3.4
HFCs	0.0	3.4	5.5	5.7	5.9	6.1	6.3
Buses	**8.5**	**12.3**	**19.0**	**20.5**	**21.8**	**21.7**	**18.0**
CO_2	8.4	11.8	18.4	19.8	21.1	21.1	17.4

[10] In 2011 FHWA changed its methods for estimating VMT and related data. These methodological changes included how vehicles are classified, moving from a system based on body-type to one that is based on wheelbase. These changes were first incorporated for the 1990 through 2008 Inventory and apply to the 2007 to 2020 time period. This resulted in large changes in VMT data by vehicle class, leading to a shift in emissions among on-road vehicle classes. This change in vehicle classification has moved some smaller trucks and sport utility vehicles from the light truck category to the passenger vehicle category in this Inventory.

CH_4	+	0.2	0.1	0.1	0.1	0.1	+
N_2O	+	+	0.1	0.1	0.2	0.2	0.1
HFCs	0.0	0.3	0.4	0.4	0.4	0.4	0.4
Motorcycles	**1.7**	**1.6**	**3.9**	**3.8**	**3.9**	**3.7**	**3.3**
CO_2	1.7	1.6	3.8	3.7	3.8	3.6	3.2
CH_4	+	+	+	+	+	+	+
N_2O	+	+	0.1	0.1	0.1	0.1	0.1
Commercial Aircraft[a]	**110.9**	**133.9**	**121.5**	**129.2**	**130.8**	**135.4**	**92.1**
CO_2	109.9	132.7	120.4	128.0	129.6	134.2	91.3
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	1.0	1.2	1.1	1.2	1.2	1.2	0.8
Other Aircraft[b]	**78.1**	**59.6**	**47.4**	**45.6**	**44.6**	**45.6**	**31.0**
CO_2	77.3	59.0	47.0	45.1	44.2	45.2	30.7
CH_4	0.1	0.1	+	+	+	+	+
N_2O	0.7	0.5	0.4	0.4	0.4	0.4	0.3
Ships and Boats[c]	**47.0**	**45.4**	**40.7**	**43.8**	**41.1**	**40.0**	**32.3**
CO_2	46.3	44.3	37.1	39.9	36.9	35.5	27.6
CH_4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
N_2O	0.3	0.3	0.2	0.2	0.2	0.2	0.2
HFCs	0.0	0.5	2.9	3.3	3.6	3.9	4.2
Rail	**39.0**	**51.5**	**40.2**	**41.4**	**42.5**	**39.7**	**34.2**
CO_2	38.5	50.8	39.6	40.7	41.8	39.1	33.7
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.3	0.4	0.3	0.4	0.4	0.3	0.3
HFCs	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Other Emissions from Electric Power[d]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pipelines[e]	**36.0**	**32.4**	**39.2**	**41.3**	**49.9**	**57.9**	**57.1**
CO_2	36.0	32.4	39.2	41.3	49.9	57.9	57.1
Lubricants	**11.8**	**10.2**	**10.4**	**9.6**	**9.2**	**8.8**	**8.0**
CO_2	11.8	10.2	10.4	9.6	9.2	8.8	8.0
Total Transportation	**1,529.6**	**1,980.3**	**1,832.4**	**1,849.6**	**1,879.5**	**1,879.1**	**1,632.4**
International Bunker Fuels[f]	*54.8*	*44.7*	*35.0*	*34.6*	*32.5*	*26.4*	*22.7*
Ethanol CO_2[g]	*4.1*	*21.6*	*76.9*	*77.7*	*78.6*	*78.7*	*68.1*
Biodisel CO_2[g]	*0.0*	*0.9*	*19.6*	*18.7*	*17.9*	*17.1*	*17.7*

+ Does not exceed 0.05 MMT CO_2 Eq.

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

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

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

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

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

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

[g] Ethanol and biodiesel CO_2 estimates are presented for informational purposes only. See Section 3.11 and the estimates in Land Use, Land-Use Change, and Forestry (see Chapter 6), in line with IPCC methodological guidance and UNFCCC reporting obligations, for more information on ethanol and biodiesel.

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

Residential

The residential end-use sector, with electricity-related emissions distributed, accounts for 15.4 percent of U.S. greenhouse gas emissions in 2020 and similarly, is heavily reliant on electricity for meeting energy needs, with electricity use for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Emissions from the residential sector have generally been increasing since 1990, and annual variations are often correlated with short-term fluctuations in energy use caused by weather conditions, rather than prevailing economic conditions. In the long term, the residential sector is also affected by population growth, migration trends toward warmer areas, and changes in housing and building attributes (e.g., larger sizes and improved insulation). A shift toward energy-efficient products and more stringent energy efficiency standards for household equipment has also contributed to recent trends in energy demand in households (EIA 2018).

Commercial

The commercial end-use sector, with electricity-related emissions distributed, accounts for 15.4 percent of U.S. greenhouse gas emissions in 2020 and is heavily reliant on electricity for meeting energy needs, with electricity use for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Energy-related emissions from the commercial sector have generally been increasing since 1990, and annual variations are often correlated with short-term fluctuations in energy use caused by weather conditions, rather than prevailing economic conditions. Decreases in energy-related emissions in the commercial sector in recent years can be largely attributed to an overall reduction in energy use driven by a reduction in heating degree days and increases in energy efficiency.

Municipal landfills and wastewater treatment are included in the commercial sector, with landfill emissions decreasing since 1990 and wastewater treatment emissions decreasing slightly.

Agriculture

The agriculture end-use sector accounts for 11.2 percent of U.S. greenhouse gas emissions in 2020 when electricity-related emissions are distributed, and includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2020, agricultural soil management was the largest source of N_2O emissions, and enteric fermentation was the largest source of CH_4 emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment such as tractors.

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

Total greenhouse gas emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy use, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of total gross domestic product as a measure of national economic activity; and (4) emissions per capita.

Table 2-14 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. Greenhouse gas emissions in the United States have decreased at an average annual rate of 0.2 percent since 1990, although changes from year to year have been significantly larger. This growth rate is slightly slower than that for total energy use, overall gross domestic product (GDP) and national population (see Table 2-14 and Figure 2-15). The direction of these trends started to change after 2005, when greenhouse gas emissions, total energy use and associated fossil fuel consumption began to peak. Greenhouse gas emissions in the United States have decreased at an average annual rate of 1.4 percent since 2005. Fossil fuel consumption has also decreased at a slower rate than

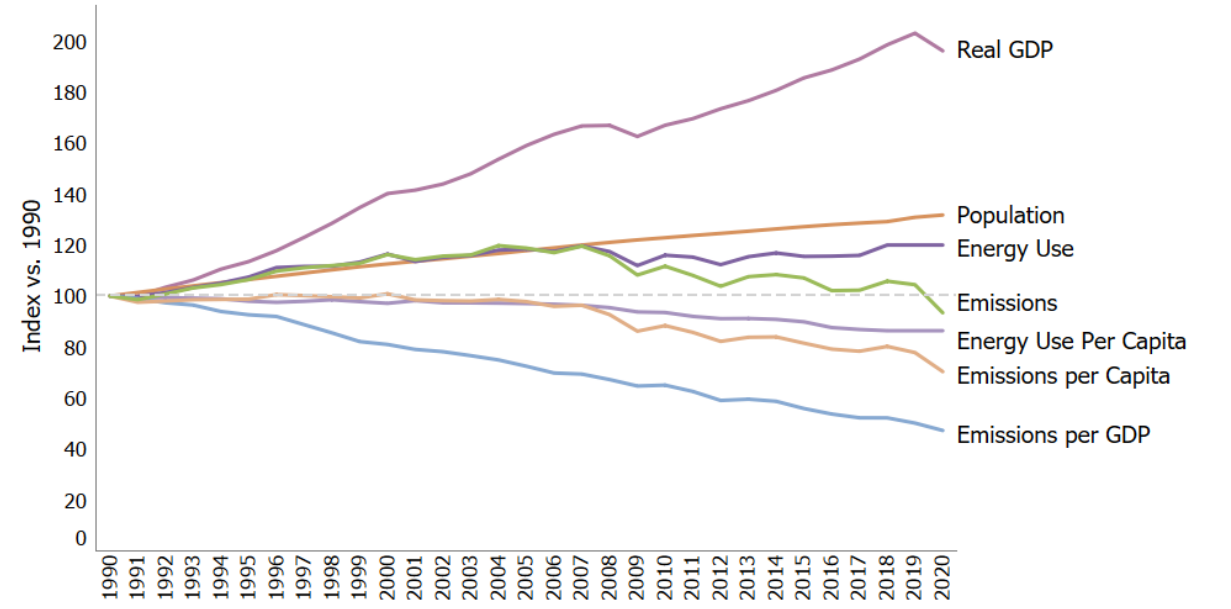
emissions since 2005, while total energy use, GDP, and national population, generally continued to increase, noting 2020 was impacted by the COVID-19 pandemic.

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

Variable	1990	2005	2016	2017	2018	2019	2020	Avg. Annual Change Since 1990[a]	Avg. Annual Change Since 2005[a]
Greenhouse Gas Emissions[b]	100	115	101	101	104	102	93	-0.2%	-1.4%
Energy Use[c]	100	119	116	116	120	119	109	0.3%	-0.5%
GDP[d]	100	159	189	193	199	203	196	2.3%	1.4%
Population[e]	100	118	128	129	129	131	132	0.9%	0.8%

[a] Average annual growth rate.
[b] GWP-weighted values.
[c] Energy-content-weighted values (EIA 2022).
[d] GDP in chained 2009 dollars (BEA 2021).
[e] U.S. Census Bureau (2021).

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



Source: BEA (2021), U.S. Census Bureau (2021), and emission estimates in this report.

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

The reporting requirements of the UNFCCC[11] request that information be provided on emissions of compounds that are precursors to greenhouse gases, which include carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2). These gases are not direct greenhouse

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

gases, but can indirectly impact Earth's radiative balance, by altering the concentrations of other greenhouse gases (e.g., tropospheric ozone) and atmospheric aerosol (e.g., particulate sulfate). Carbon monoxide is produced when carbon-containing fuels are combusted incompletely in energy, transportation, and industrial processes, and is also emitted from practices such as agricultural burning and waste disposal and treatment. Anthropogenic sources of nitrogen oxides (i.e., NO and NO_2) are primarily fossil fuel combustion (for energy, transportation, industrial process) and agricultural burning. Anthropogenic sources of NMVOCs, 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, oil and natural gas production, waste practices, agricultural burning, 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.

As noted above and summarized in Chapter 6 of IPCC (2021), these compounds can have important indirect effects of Earth's radiative balance. For example, reactions between NMVOCs and NO_x in the presence of sunlight lead to tropospheric ozone formation, a greenhouse gas. Concentrations of NMVOCs, NO_x, and CO can also impact the abundance and lifetime of primary greenhouse gases. This largely occurs by altering the atmospheric concentrations of the hydroxyl radical (OH), which is the main sink for atmospheric CH_4. For example, NO_x emissions can lead to increases in O_3 concentrations and subsequent OH production, which will increase the amount of OH molecules that are available to destroy CH_4. In contrast, NMVOCs and CO can both react directly with OH, leading to lower OH concentrations, a longer atmospheric lifetime of CH_4, and a decrease in CO_2 production (i.e., CO+OH→ CO_2). Changes in atmospheric CH_4 can also feedback on background concentrations of tropospheric O_3. Other indirect impacts include the formation of sulfate and nitrate aerosol from emissions of NO_x and SO_2, both of which have a net negative impact on radiative forcing.

Since 1970, the United States has published triennial estimates of emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2021b), which are regulated under the Clean Air Act. Emissions of each of these precursor greenhouse gases has decreased significantly since 1990 as a result of implementation of Clean Air Act programs, as well as technological improvements.[12] Precursor emission estimates for this report for 1990 through 2020 were obtained from data published on EPA's National Emissions Inventory (NEI) Air Pollutants Emissions Trends Data website (EPA 2021b). For Table 2-15, NEI-reported emissions of CO, NO_x, SO_2, and NMVOCs are recategorized from NEI Tier 1/Tier 2 source categories to those more closely aligned with IPCC categories, based on EPA (2022) and detailed in Annex 6. Table 2-15 shows that fuel combustion accounts for the majority of emissions of these precursors. 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. Precursor emissions from Agriculture and LULUCF categories are estimated separately and therefore are not taken from EPA (2021b); see Sections 5.7, 6.2, and 6.6.

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

Gas/Activity	1990	2005	2016	2017	2018	2019	2020
NO_x	**21,764**	**17,333**	**8,792**	**8,483**	**8,008**	**7,425**	**7,128**
Energy	21,106	16,602	8,268	7,883	7,456	6,962	6,471
IPPU	592	572	402	397	397	397	397
LULUCF	52	142	107	188	139	50	244
Agriculture	13	15	14	14	14	14	14
Waste	+	2	1	1	1	1	1
CO	**132,759**	**74,553**	**39,981**	**43,688**	**39,531**	**34,170**	**43,799**
Energy	125,640	64,985	34,461	33,401	32,392	31,384	30,376
LULUCF	2,673	7,642	4,099	8,936	5,789	1,436	12,074
IPPU	4,129	1,557	1,075	1,007	1,007	1,007	1,007
Agriculture	315	363	340	339	338	337	336
Waste	1	7	6	5	5	5	5

[12] More information is available online at: https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health and https://gispub.epa.gov/neireport/2017/.

NMVOCs	**20,923**	**13,309**	**9,855**	**9,483**	**9,310**	**9,136**	**8,963**
Energy	12,612	7,345	6,022	5,664	5,491	5,318	5,145
IPPU	7,638	5,849	3,776	3,767	3,767	3,767	3,767
Waste	673	114	57	52	52	52	52
Agriculture	NA	NA	NA	NA	NA	NA	NA
LULUCF	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**2,906**	**2,303**	**2,211**	**1,943**	**1,780**
Energy	19,628	12,364	2,439	1,794	1,701	1,433	1,270
IPPU	1,307	831	466	509	509	509	509
Waste	+	1	1	1	1	1	1
Agriculture	NA	NA	NA	NA	NA	NA	NA
LULUCF	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 2021b) except for estimates from Forest Fires, Grassland Fires, and Field Burning of Agricultural Residues. Emission categories from EPA (2021b) are aggregated into IPCC categories following as shown in Table ES-3.