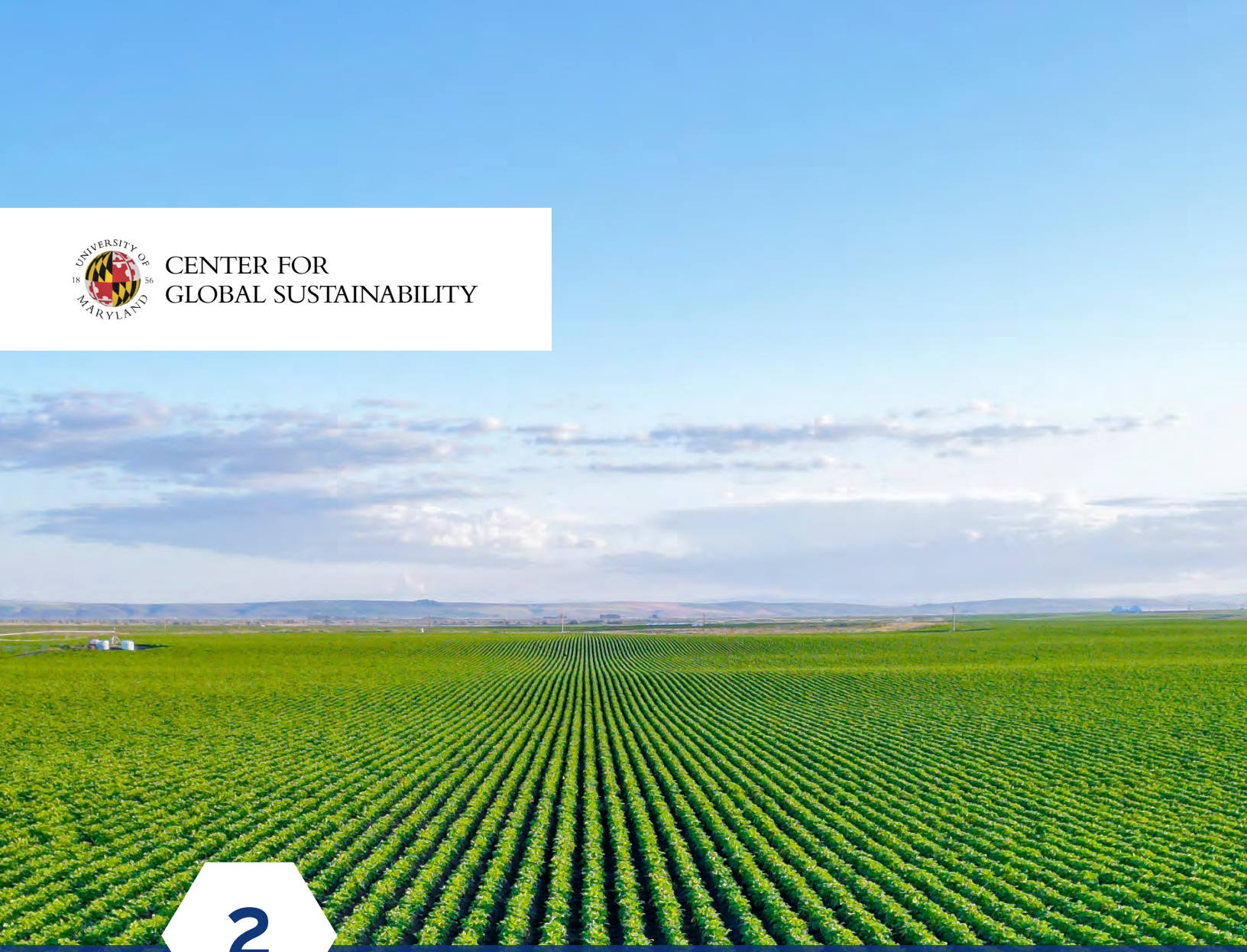

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Trends in Greenhouse Gas Emissions and Removals

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Suggested Citation

M. Desai, W. Irving. (2026). Chapter 2. Trends in Greenhouse Gas Emissions and Removals. In Desai et al., *Greenhouse Gas Inventory and Analysis for the United States*: 1990-2024 (pp. 2-1 to 2-23). Center for Global Sustainability, University of Maryland, College Park.

Chapter 2. Trends in Greenhouse Gas Emissions and Removals

This chapter describes national greenhouse gas (GHG) emission trends by sector and by GHG. Emissions for non-carbon dioxide (CO_2) GHGs are presented as carbon dioxide equivalents (CO_2 Eq.) using the 100-year global warming potential (GWP) values contained in the *Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report* (IPCC, 2013). Converting emissions into CO_2 Eq. allows the radiative forcing effect of various gas emissions in the atmosphere to be compared.

Gross vs. Net Greenhouse Gas Emissions Totals

Gross emissions represent the total GHGs produced by human activities (e.g., from energy, industry, agriculture, waste activities) without considering anthropogenic (human-caused) CO_2 removals from the atmosphere through sinks (e.g., land use, land-use change, forestry), while net emissions account for all anthropogenic emissions and removals, including those through sinks.

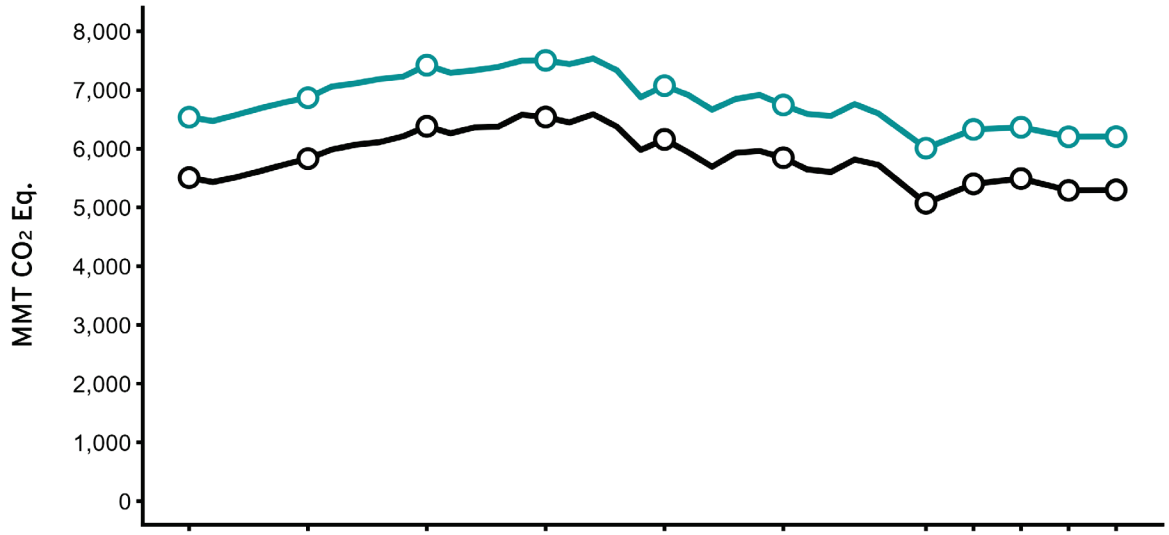
2.1 Aggregated Greenhouse Gas Emission and Removal Trends

Overall Trends

As shown in Figure 2-1, in 2024, total gross U.S. GHG emissions were 6,205.3 million metric tons of CO_2 Eq. (MMT CO_2 Eq.). This total is a 5.1 percent decrease from 1990 and a 0.04 percent annual increase from 2023. The decreasing trend since around 2005 is associated with a decrease in CO_2 emissions from fossil fuel combustion, which is discussed in more detail below and in Chapter 3 (Energy).

In 2024, total net U.S. GHG emissions, including emissions and sinks through land use, land-use change and forestry (LULUCF), were 5,298.8 MMT CO_2 Eq. This total is a 3.8 percent decrease from 1990 and a 0.2 percent annual increase from 2023. Sequestration of CO_2 in the LULUCF sector offset the equivalent of 14.6 percent of total gross emissions in 2024 (906.5 MMT CO_2 Eq.).

Figure 2-1: U.S. Gross and Net Emissions

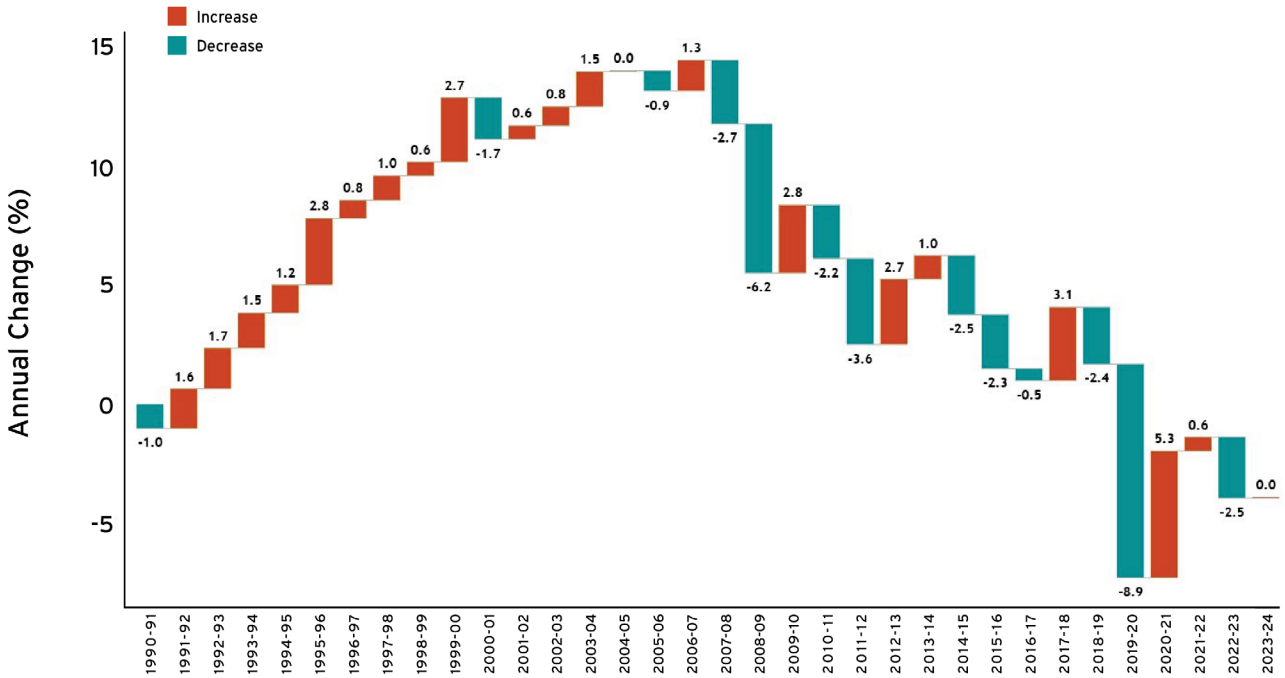


	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Gross Emissions	6,536	6,868	7,422	7,504	7,073	6,744	6,010	6,328	6,365	6,203	6,205	-5.1%
Net Emissions	5,507	5,831	6,381	6,539	6,159	5,846	5,071	5,402	5,491	5,290	5,299	-3.8%

Annual Changes in Emissions

Figure 2-2 shows the annual changes in gross emissions over the time series. Note that emissions dropped significantly in 2020–2021 due to the COVID-19 pandemic but have since partially rebounded.

Figure 2-2: Annual Percent Change in U.S. Gross Emissions

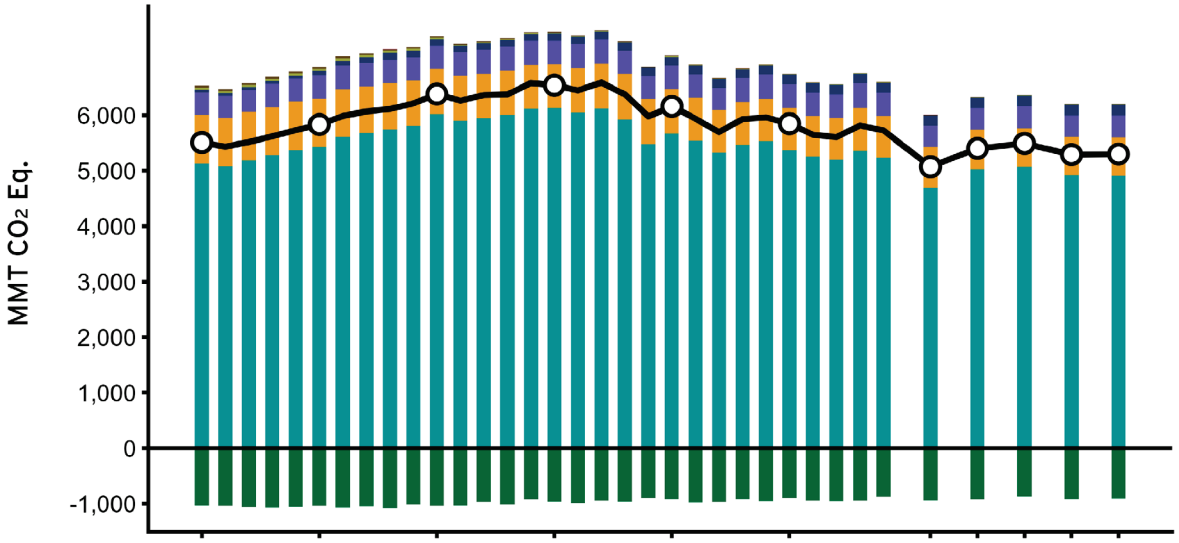


2.2 Emission and Removal Trends

Emissions and Removals by Gas

Figure 2-3 illustrates the trend in U.S. GHG emissions broken out by individual GHGs, in CO_2 Eq. (i.e., weighted by GWP).

Figure 2-3: Trends in Greenhouse Gas Emissions and Sinks by Gas



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
CO_2	5,130	5,431	6,019	6,125	5,664	5,366	4,694	5,018	5,066	4,924	4,912	-4.3%
CH_4	873	867	818	797	810	764	731	715	696	685	687	-21.3%
N_2O	408	423	413	425	421	429	391	396	399	388	398	-2.4%
HFCs	48	74	116	125	159	168	178	184	190	191	194	306.9%
SF_6	38	35	27	20	12	8	8	8	7	8	8	-79.6%
PFCs	40	37	29	10	7	7	7	6	7	6	6	-85.6%
NF_3	+	+	1	1	1	1	1	1	1	1	1	335.8%
LULUCF Net	(1,029)	(1,037)	(1,040)	(965)	(914)	(898)	(939)	(927)	(874)	(913)	(907)	11.9%
Net Emissions	**5,507**	**5,831**	**6,381**	**6,539**	**6,159**	**5,846**	**5,071**	**5,402**	**5,491**	**5,290**	**5,299**	**-3.8%**

CO_2 contributes the largest share to national GHG totals each year and has the greatest impact on both year-to-year changes and on the overall trend since 1990. Gross CO_2 emissions decreased by 4.3 percent from 1990 to 2024 and decreased by 0.3 percent from 2023 to 2024. Fossil fuel combustion for energy makes up the large majority (over 90 percent) of gross CO_2 emissions. For a more detailed discussion of fossil fuel-related trends, including contributions from electricity, transportation, residential and commercial buildings, see the Energy Sector and Trends in Focus sections, as well as Chapter 3. U.S. forests, croplands and other types of lands have resulted in a

net sink of CO_2 emissions each year since 1990, offsetting between the equivalent of approximately 12.3 percent to 16.1 percent of gross emissions each year.

Methane (CH_4) emissions make up the second largest share of total gross GHG emissions, ranging from 13 percent in 1990 to 11 percent in 2024. The long-term moderately declining trend of CH_4 emissions results from a variety of distinct contributing factors, including increases from some larger source categories (e.g., livestock manure management), decreases from other categories (e.g., landfills, coal mining), and categories where little has changed at an aggregate level (e.g., livestock enteric fermentation).

Nitrous oxide (N_2O) emissions have remained at comparable levels since 1990. A small overall decrease can be attributed to lower tailpipe emissions of N_2O from mobile combustion, as automobile catalytic converter technology targeting nitrogen oxides improved. By far the largest share of N_2O emissions comes from agricultural soil management (e.g., application of fertilizer and other management practices). The overall level of N_2O emissions from agriculture increased by approximately 7 percent since 1990, and its share of total N_2O emissions increased from approximately 70 percent in 1990 to 77 percent in 2024.

Fluorinated GHGs include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). HFCs make up by far the largest share of fluorinated GHG emissions, with their use as substitutes for ozone-depleting substances (ODS) increasing significantly since 1990 and then leveling off in recent years. PFC emissions have decreased overall due to reductions from fluorochemical production and primary aluminum production. SF_6 emissions have also declined from the two largest sources, electrical equipment and magnesium production.

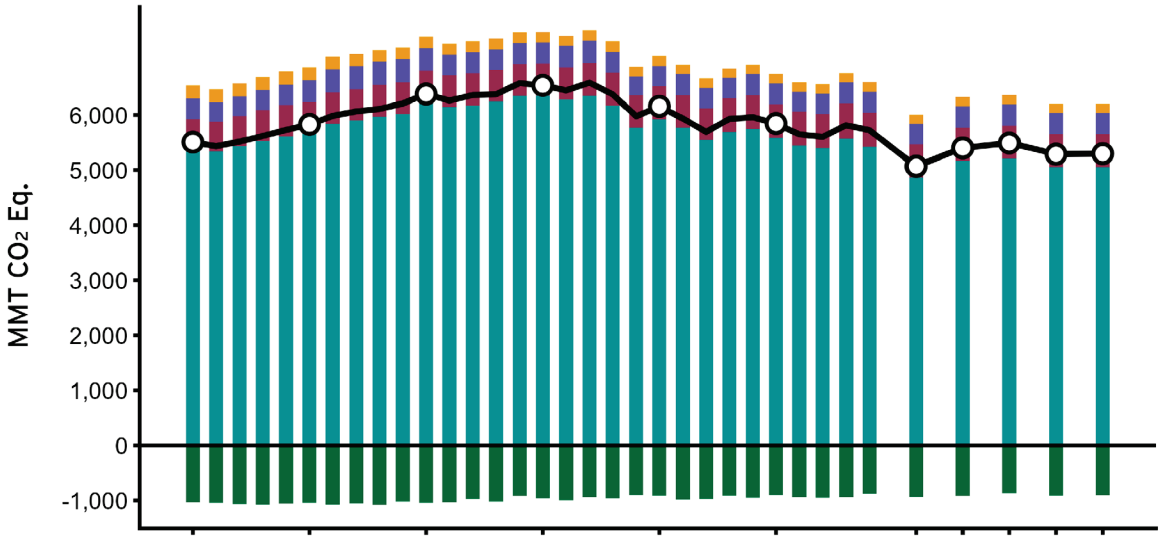
Emissions and Removals by Sector

Overview

Emissions and removals can also be categorized into the set of five sectors defined by the international inventory reporting guidelines and in the methodological framework provided by the Intergovernmental Panel on Climate Change (IPCC). Global adoption of this framework facilitates comparability across countries and provides additional insights into the economic drivers of national emissions and their changes over time.

Figure 2-4 shows total emissions since 1990 broken out by IPCC sector. The energy sector, which includes fossil fuel combustion, fugitive emissions, non-energy use of fossil fuels, and additional smaller categories, has the largest impact on the overall trend. Energy sector emissions peaked in 2005 at 18 percent above 1990 levels and subsequently declined to 6.1 percent above 1990 levels by 2024. For more information on the underlying factors influencing these trends, see the Energy Sector and Trends in Focus sections, which present information on transportation and electricity generation, and Chapter 4.

Figure 2-4: Trends in Greenhouse Gas Emissions and Sinks by Sector



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Energy	5,380	5,661	6,241	6,354	5,918	5,580	4,864	5,169	5,207	5,055	5,051	-6.1%
Agriculture	551	574	567	583	600	616	600	601	603	595	602	9.3%
IPPU	369	400	414	375	372	377	376	392	390	387	387	4.7%
Waste	236	234	200	192	183	171	170	167	165	166	166	-29.6%
LULUCF Net	(1,029)	(1,037)	(1,040)	(965)	(914)	(898)	(939)	(927)	(874)	(913)	(907)	11.9%
Net Emissions	**5,507**	**5,831**	**6,381**	**6,539**	**6,159**	**5,846**	**5,071**	**5,402**	**5,491**	**5,290**	**5,299**	**-3.8%**

The industrial processes and product use (IPPU) and agriculture sectors have remained largely stable in terms of total emissions over the time series, while the share of overall emissions has increased marginally as emissions in the energy sector have decreased. For both the IPPU and agriculture sectors, there are more distinct changes at the category level, which are discussed in further detail below and in Chapters 4 and 5.

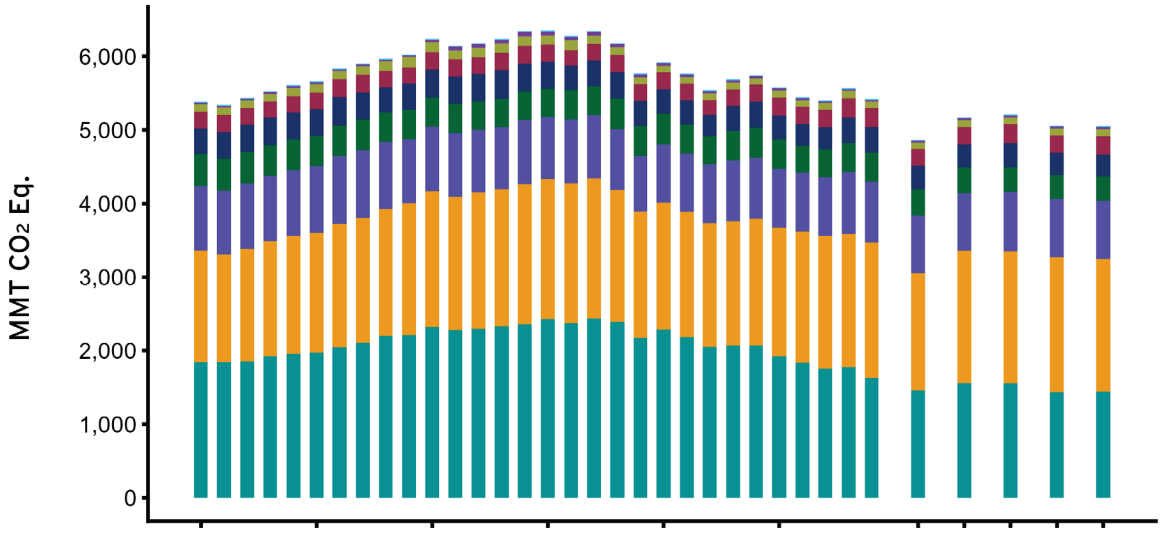
As discussed in the Emissions Removal by Gas section, the LULUCF sector, including forests, croplands and other types of lands, have been a large but slightly declining net sink of CO_2 emissions each year since 1990, with a total offset of gross emissions of 14.6 percent in 2024. The largest share of total net fluxes (sequestration) comes from existing forests, which are discussed in more detail in Chapter 6.

The waste sector is dominated by CH_4 emissions from municipal solid waste landfills, which have declined since 1990, with smaller contributions from wastewater, composting, and anaerobic digestion.

Energy Sector

Figure 2-5 shows the IPCC energy sector time series, broken out by a mix of categories and economic sectors where fossil fuel combustion occurs. Chapter 3 provides a detailed discussion of the emissions levels and trends for each energy category, along with detailed methodological information. Gases included in the IPCC energy sector are CO_2, CH_4, and N_2O. Note that under a different "Economic sector" classification scheme, a share of emissions of HFCs and SF_6 also attributed to energy-related sources (e.g., for mobile air conditioning or electricity transmission equipment).

Figure 2-5: Trends in Energy Sector Greenhouse Gas Sources



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Transportation Fossil Fuel Combustion	1,518	1,629	1,845	1,900	1,726	1,741	1,594	1,792	1,797	1,837	1,808	19.1%
Electric Power Fossil Fuel Combustion	1,839	1,967	2,319	2,428	2,287	1,926	1,459	1,561	1,553	1,433	1,438	-21.8%
Industrial Fossil Fuel Combustion	875	911	880	848	794	807	782	790	811	795	793	-9.4%
Fugitive Emissions	440	413	396	387	405	396	360	342	328	324	327	-25.6%
Residential Fossil Fuel Combustion	345	360	378	364	342	324	318	318	335	305	295	-14.6%
Commercial Fossil Fuel Combustion	228	230	239	229	227	247	231	236	257	231	252	10.4%
Non-Energy Use of Fuels	101	114	133	132	91	96	84	90	89	90	96	-4.5%
U.S. Territories Fossil Fuel Combustion	20	22	37	52	34	28	23	26	24	27	28	39.4%
Incineration of Waste	13	15	13	14	13	15	13	13	13	13	12	-8.1%
CO_2 Transport, Injection & Storage	+	+	+	+	+	+	+	+	+	+	+	NA
Total Emissions	**5,380**	**5,661**	**6,241**	**6,354**	**5,918**	**5,580**	**4,864**	**5,169**	**5,207**	**5,055**	**5,051**	**-6.1%**

Fossil Fuel Combustion CO_2

Fossil fuel combustion of coal, petroleum, and natural gas is by far the most important contributor to the overall energy sector trend, with CO_2 being the primary gas. CO_2 from fossil fuel combustion has accounted for approximately 74 percent of CO_2 Eq. U.S. total gross emissions on average across the time series and accounted for 93 percent of total U.S. CO_2 emissions in 2024.

Fossil fuel combustion CO_2 emissions decreased by 3.8 percent (180.7 MMT CO_2 Eq.) from 1990 to 2024 and were responsible for most of the decrease in national emissions during this period. Similarly, CO_2 emissions from fossil fuel combustion have decreased by 20.3 percent (1,166.9 MMT CO_2 Eq.) since 2005. From 2023 to 2024, these emissions decreased by 0.3 percent (13.6 MMT CO_2 Eq.).

The main long-term (e.g., decadal) factors influencing fossil fuel combustion emissions include population and economic growth, technological changes, and the carbon intensity of energy fuel choices. Producing a unit of heat or electricity using natural gas instead of coal, for example, reduces CO_2 emissions because of the lower carbon content of natural gas. The shift from coal toward natural gas for electricity generation over time has been a main driver of emission reductions.

On a shorter-term time scale (e.g., year to year), the overall consumption and mix of fossil fuels in the United States fluctuates 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. Significant unique events, such as the COVID-19 pandemic starting in 2020, can also have a major impact on annual changes.

As shown in Figure 2-5, fossil fuel combustion (as defined by the IPCC) can be further disaggregated into five general energy end-use sectors: transportation, electricity, industrial, commercial, and residential.[1] As noted below, the transportation and electricity sectors have the largest impact on overall emissions and the trend since 1990.

Transportation. The transportation sector has represented the largest source of CO_2 emissions from fossil fuel combustion (mainly petroleum) since 2017. Emissions increased by 21 percent since 1990 but decreased 2 percent from 2023 to 2024. The fuel economy of new light-duty vehicles declined between 1990 and 2004, coinciding with the increasing market share of light-duty trucks (from about 29.6 percent of new vehicle sales in 1990 to 48.0 percent in 2004). Starting in 2005, vehicle fuel economy began to improve, slowing the rate of increase of CO_2 emissions. For more detailed information on emissions trends related to transportation, see the Trend in Focus section below and Chapter 3 (Energy) of this *Greenhouse Gas Inventory and Analysis for the United States (GHGIA)*.

Electricity. In 1990, the electricity sector was the largest source of GHG emissions in the United States, representing one-third of the total (gross). Emissions peaked in the 2004-2006 period and then declined to 22 percent below 1990 levels in 2024. In 2024 the electricity sector represented

[1] This *GHGIA* uses the classification system from the Energy Information Administration to allocate fuel use and emissions across these energy consuming sectors (https://www.eia.gov/totalenergy/data/monthly/pdf/sec13.pdf).

24 percent of all U.S. GHG emissions (gross), second to transportation. The decline in emissions over the last two decades is due to a shift away from coal to less carbon-intensive natural gas and a smaller but growing share of renewable energy generation. The efficiency of electricity consumption has improved steadily throughout the time series, leading to lower emissions each year than would have otherwise occurred. For more detailed information on emissions trends related to electricity, see the Trends in Focus section below and Chapter 3 (Energy) of this *GHGIA*.

Industry. The Energy Information Administration (EIA) statistics for the industry sector include all facilities and equipment used for producing, processing, or assembling goods. From 1990 to 2024, direct energy emissions from the industrial sector decreased by 9.4 percent, as industrial output shifted in relative terms from energy-intensive manufacturing products (e.g., steel) to less energy-intensive products (e.g., computer equipment).

Residential. EIA's fuel consumption data for the residential sector consists of living quarters for private households, primarily oil and gas for heating and cooking needs. Although emissions have not changed significantly since 1990, the residential sector can fluctuate from year to year based on the severity of winters and summers and the associated demands on fuel use.

Commercial. EIA's fuel consumption data for the commercial sector consists of service-providing facilities and equipment from private and public organizations and businesses. As with the residential sector, commercial sector emissions have not changed significantly since 1990.

Other Energy Sector Categories

Non-energy use of fossil fuels. A small but important share of fossil fuels consumed each year in the United States is converted into short- and long-lived products (e.g., lubricants, plastics, asphalt). These products can release CO_2 over time during use and after disposal. Emissions from this category have increased slightly since 1990 but do not experience significant annual variations.

Fugitive emissions. Fugitive emissions include CO_2 and CH_4 and occur from the production, processing, transport, and distribution of coal, petroleum, and natural gas before the fuels are ultimately consumed. Although aggregate fugitive emissions have not changed significantly since 1990, emissions of some subcategories decreased significantly (e.g., CH_4 from coal mining), while others increased (e.g., CO_2 from petroleum systems). For more information on fugitive emissions, see Chapter 3 (Energy).

CO_2 emissions can also occur as the gas is transported, injected, and stored in geologic formations (i.e., for enhanced oil recovery or permanent storage in saline formations). This industry is a relatively small source of CO_2 emissions and does not impact the energy sector trend.

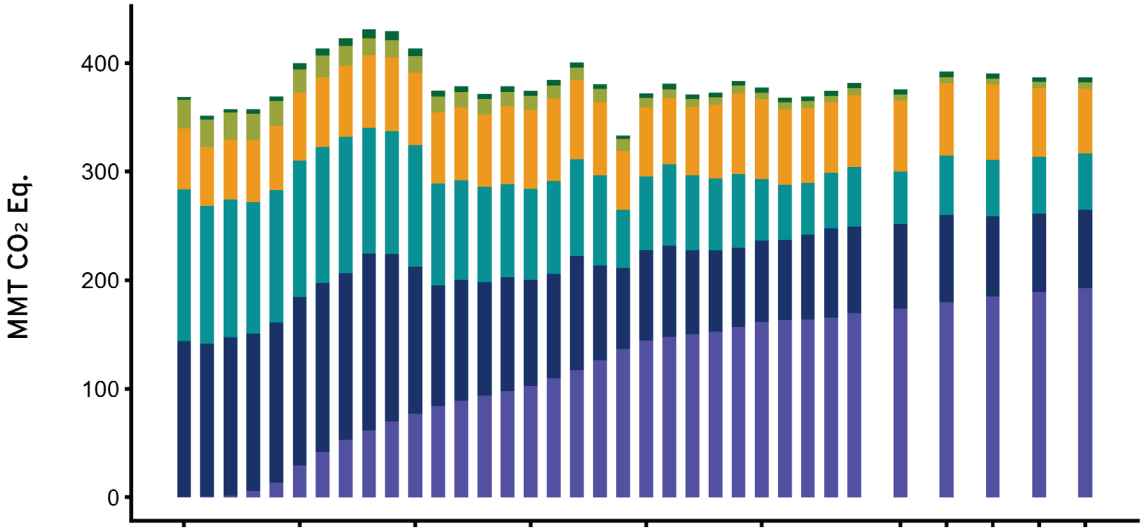
Energy emissions also include some categories that are not added to energy sector totals but are instead presented as memo items, including international bunker fuels and biomass emissions.

Industrial Processes and Product Use Sector

The IPCC IPPU sector includes the diversity of industry-related sources with the exclusion of fossil fuel use for energy at industrial facilities (captured in the IPCC energy sector). Figure 2-6 shows the IPPU trend from 1990 broken out by common groups of sources: minerals, metals, chemicals, use of substitutes for ODSs, electronics, and "other" sources.

Although the overall IPPU trend from 1990 is a modest 4.7 percent increase, and IPPU has a minor impact on the overall U.S. emissions trend, some IPPU categories with notable increases and decreases are described below. For a detailed description of IPPU data and methods, see Chapter 4.

Figure 2-6: Trends in Industrial Processes and Product Use Sector Greenhouse Gas Sources (MMT CO_2 Eq.)



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Substitution of Ozone Depleting Substances	0.3	29.6	77.2	102.7	144.6	161.5	173.7	179.9	184.9	189.0	192.4	76,013%
Chemical Industry	143.6	154.7	135.2	97.9	83.3	74.6	77.8	80.2	74.2	72.2	72.7	-49.4%
Mineral Industry	56.0	62.7	66.4	73.0	63.2	73.1	65.7	66.6	69.2	63.2	59.0	5.4%
Metal Industry	139.9	125.8	112.2	83.3	67.9	57.0	48.1	54.5	51.8	52.2	52.2	-62.7%
Other Product Manufacture and Use	26.1	21.3	15.5	13.3	9.2	6.5	6.2	6.0	5.5	6.1	6.1	-76.7%
Electronics Industry	3.3	5.7	7.1	4.5	3.9	4.6	4.5	4.9	4.8	4.2	4.2	27.2%
Total Emissions	**369.2**	**399.8**	**413.5**	**374.7**	**372.0**	**377.4**	**376.1**	**392.2**	**390.4**	**387.0**	**386.6**	**4.7%**

Substitutes for ODS. Emissions of HFCs started to increase dramatically in the 1990s as they were introduced to replace ozone-depleting chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs). In 2024, ODS substitute emissions made up 50 percent of total IPPU emissions.

Chemicals. Emissions decreased substantially from fluorochemical, adipic acid, and nitric acid production, contributing to an overall reduction from the chemical production industry since 1990. Petrochemical production emissions increased by 43 percent during this period.

Metals. Emissions from iron and steel production decreased significantly since 1990, with 2024 emissions at 55 percent below 1990 levels. This decrease corresponds with a more general decrease in output from the iron and steel industry, as well as shifts to more energy-efficient production approaches. Emissions of CO_2 and PFCs from aluminum production decreased by 94 percent during the same period due to a combination of aluminum recycling, reduced primary production, increasing use of clean energy, and technological and process improvements at production facilities.

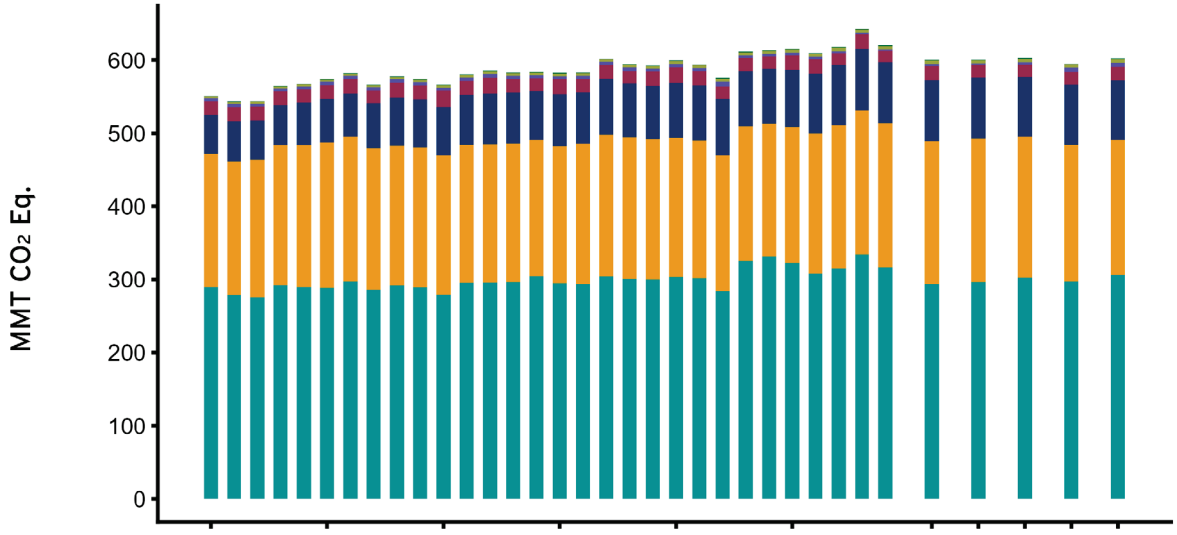
Other product manufacture and use. Emissions of SF_6 used in electrical equipment declined by 38 percent since 1990 as industry implemented efforts to reduce leakage.

Agriculture Sector

The IPCC agriculture sector includes emissions resulting from livestock management (e.g., enteric fermentation and manure management), rice cultivation, agricultural soil management, liming, urea fertilization, and field burning of agricultural residues. CH_4 and N_2O are the primary GHGs emitted by agricultural activities, with small amounts of CO_2 also emitted. Note that consistent with the *IPCC Guidelines*, carbon stock changes from agricultural lands are included in the LULUCF sector (see Chapter 5).

As shown in Figure 2-7, the overall trend in the agriculture sector from 1990 to 2024 is a 9.3 percent increase. Annual changes are also modest and typically reflect changes in weather patterns, fertilizer use, livestock populations, and crop production. Emissions from the largest agriculture category, N_2O from soil management, increased by 6 percent since 1990, whereas livestock enteric fermentation emissions did not change significantly. Livestock manure management is the exception, with a 55.8 percent increase in methane emissions from 1990 as livestock operations have become more concentrated in fewer, larger operations, resulting in a shift toward more liquid-based manure management practices (e.g., lagoons).

Figure 2-7: Trends in Agriculture Sector Emissions



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Agricultural Soil Management	289.1	287.9	279.1	294.7	303.4	322.4	293.0	296.5	302.5	297.3	306.7	6.1%
Enteric Fermentation	182.8	199.2	190.2	188.2	190.8	185.9	196.3	196.5	192.6	187.2	184.1	0.7%
Manure Management	52.5	60.1	66.5	70.2	74.4	78.5	83.8	83.6	81.7	81.9	81.8	55.8%
Rice Cultivation	18.9	19.1	22.4	20.6	21.5	19.6	18.6	16.3	16.8	17.5	18.1	-4.3%
Liming	4.7	4.4	4.4	4.4	4.7	3.7	2.9	2.4	3.2	5.4	5.5	18.1%
Urea Fertilization	2.3	2.6	3.3	3.6	4.0	4.6	4.7	4.5	4.8	4.7	5.1	121.4%
Field Burning of Agricultural Residues	0.7	0.6	0.7	0.8	0.9	0.7	0.8	0.8	0.8	0.9	0.8	18.4%
Total Emissions	**551.0**	**573.9**	**566.7**	**582.5**	**599.9**	**615.5**	**600.2**	**600.6**	**602.5**	**594.9**	**602.1**	**9.3%**

Land Use, Land-Use Change, and Forestry Sector

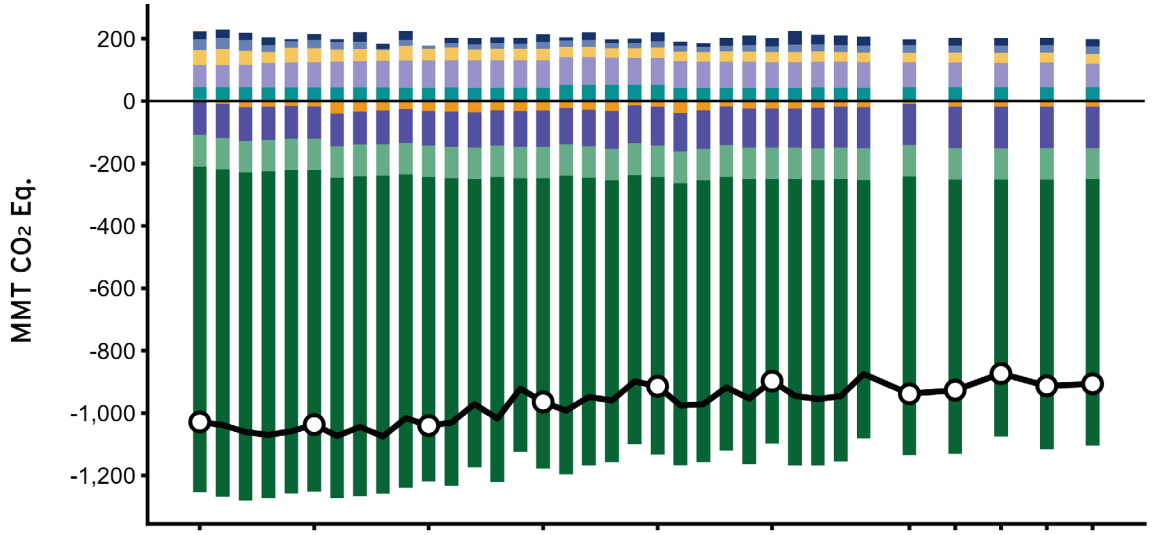
The LULUCF sector includes the entirety of anthropogenic impacts on fluxes of CO_2, CH_4, and N_2O from managed land.[2] Consistent with the IPCC Guidelines, this *GHGIA* presents GHG emissions and removals in the LULUCF sector by the six general managed land-use categories, as well as conversions between these categories: forest land, cropland, grassland, wetlands, settlements, and "other land."

Overall, including the net impact of both emissions and removals (from the atmosphere), the LULUCF sector has been a large net sink each year since 1990 (see Figure 2-8). Existing forests have made up by far the largest share of this net sink, offsetting the equivalent of 15.7 percent of total U.S. gross emissions in 1990 and decreasing slightly to a 14.6 percent offset equivalent in

[2] See Chapter 6 for more information on the definition of managed land area classifications in the United States.

2024. This decline in sequestration is the aggregate result of various underlying drivers, including aging forests, which sequester less carbon per year, and increased frequency and severity of forest disturbances (e.g., wildfire, weather, pest outbreaks, disease). Forest fires can also cause large annual changes in CH_4 and N_2O emissions, but to date these non-CO_2 gases have not had a major impact on annual GHG fluxes or the overall LULUCF trend.

Figure 2-8: Trends in LULUCF Sector Emissions and Removals



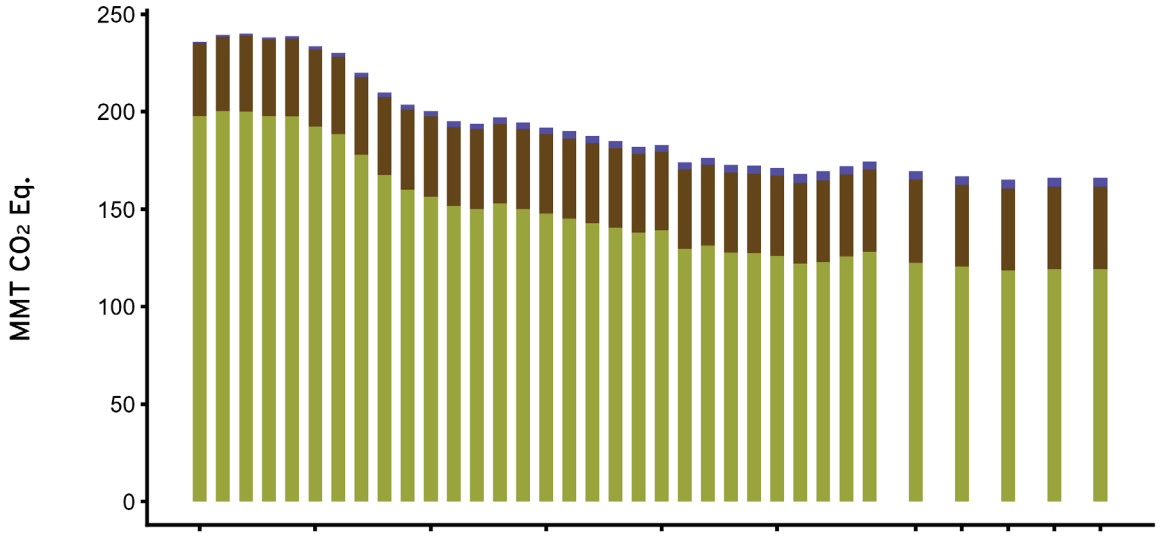
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Forest Land Remaining Forest Land	(1,043.1)	(1,031.0)	(975.5)	(930.9)	(890.8)	(848.0)	(892.9)	(879.0)	(822.9)	(864.9)	(854.8)	18.1%
Land Converted to Forest Land	(100.8)	(100.9)	(101.0)	(101.2)	(101.3)	(101.5)	(100.9)	(100.9)	(100.8)	(100.8)	(100.9)	-0.1%
Cropland Remaining Cropland	1.0	(16.6)	(30.9)	(31.0)	(18.7)	(23.5)	(9.6)	(17.7)	(18.6)	(18.1)	(18.0)	-1,832%
Land Converted to Cropland	48.5	44.8	36.4	35.5	34.4	32.1	29.6	32.2	32.3	32.5	32.6	-32.9%
Grassland Remaining Grassland	24.2	19.1	(1.1)	24.5	27.4	25.3	17.0	24.7	23.2	23.2	22.9	-5.3%
Land Converted to Grassland	35.6	27.4	11.5	21.9	19.9	19.0	25.1	23.0	23.7	24.1	24.7	-30.6%
Wetlands Remaining Wetlands	38.5	39.2	40.1	40.9	50.3	39.8	44.0	43.9	44.0	43.9	44.0	14.4%
Land Converted to Wetlands	6.7	4.7	2.6	1.9	1.1	0.8	0.8	0.8	0.8	0.8	0.8	-88.1%
Settlements Remaining Settlements	(109.1)	(104.2)	(111.0)	(115.2)	(123.4)	(125.9)	(131.9)	(132.5)	(132.6)	(132.6)	(131.9)	-21.0%
Land Converted to Settlements	69.5	80.4	88.3	89.0	86.6	84.0	80.3	78.8	77.3	78.4	74.1	6.6%
LULUCF Sector Net Total	**(1,028.9)**	**(1,037.2)**	**(1,040.5)**	**(964.7)**	**(914.4)**	**(897.9)**	**(938.6)**	**(926.7)**	**(873.8)**	**(913.4)**	**(906.5)**	**11.9%**

Waste Sector

The IPCC waste sector consists of municipal solid waste landfills, domestic and industrial wastewater treatment, composting, and biogas facilities. Emissions of CH_4 result from the decomposition of organic matter in anaerobic conditions, and N_2O results from bacterial nitrification and denitrification processes.

As shown in Figure 2-9, landfills make up the majority of waste sector emissions through methane escaping from the surface and through on-site equipment. Landfill methane emissions declined by 40 percent from 1990 to 2024 from a variety of factors, including increased use of gas collection systems and increasing diversion of some decomposable materials (e.g., cardboard) to other treatment options (e.g., recycling).

Figure 2-9: Trends in Waste Sector Emissions



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Landfills	197.8	192.3	156.4	147.7	139.0	126.0	122.6	120.7	118.6	119.4	119.4	-39.6%
Wastewater Treatment and Discharge	37.5	39.6	41.1	40.7	40.4	41.2	42.5	41.8	42.1	42.2	42.1	12.5%
Composting	0.7	1.7	2.9	3.6	3.5	4.1	4.4	4.4	4.4	4.4	4.5	513.6%
Anaerobic Digestion at Biogas Facilities	+	+	+	+	+	+	+	+	+	+	+	986.3%
Total Emissions	**235.9**	**233.6**	**200.3**	**192.0**	**182.9**	**171.3**	**169.5**	**166.8**	**165.2**	**166.0**	**166.0**	**-29.6%**

Emissions and Removals by Economic Sector

This section presents U.S. GHG emission according to more commonly used economic sectors. A main difference from the reporting sectoral classification is that fossil fuel combustion emissions are allocated to the U.S. economic sector in which they are consumed, rather than included solely in the energy sector. The result is similar to how fossil fuel combustion is subcategorized in the IPCC classification (e.g., electricity, transportation, industry), except for the inclusion of some combustion emissions under agriculture.

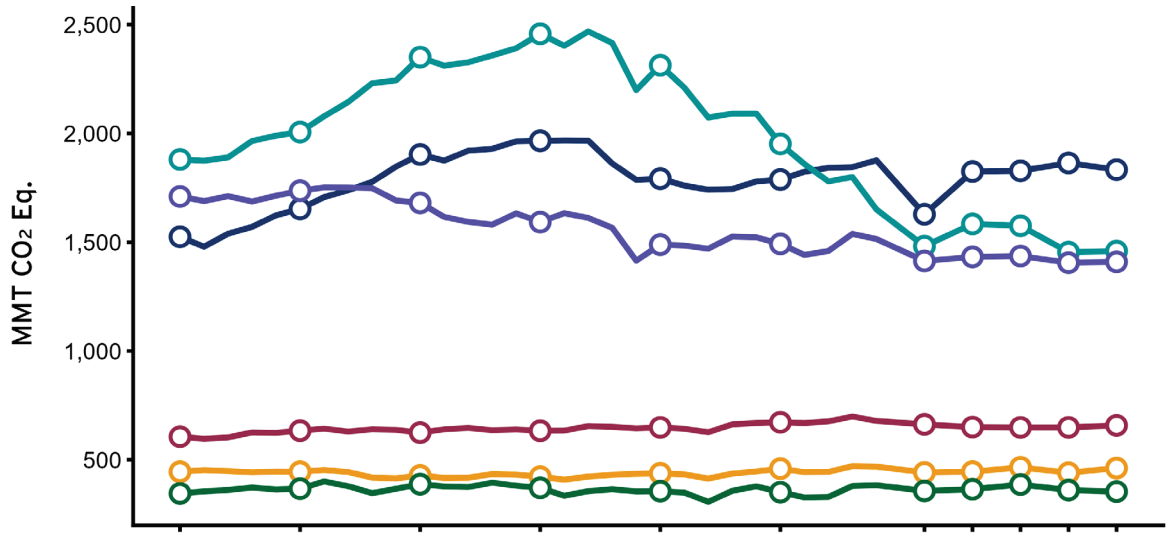
Industrial emissions now include both fossil fuel combustion and most IPPU emissions (e.g., process emissions from iron and steel, aluminum, chemical production).[3] As a result, the Industry economic sector makes up a much larger share of total U.S. emissions than the IPPU results. Figure 2-10 shows the trends by economic sector since 1990.

The overall trend highlights are largely the same in this classification as they are for the IPCC fossil fuel combustion results. Transportation is the largest sector, followed by electricity and then industry. All three experienced a significant drop in 2020 due to the onset of COVID-19.

The agriculture, commercial, and residential economic sectors all remained at roughly the same levels from 1990 to 2024, with some year-to-year changes related to weather and other factors.

[3] Some exceptions include SF_6 from electrical equipment, which is with electric power, and HFCs from mobile air conditioning systems, which are with transportation.

Figure 2-10: Trends by Economic Sector



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Transportation	1,525	1,653	1,903	1,966	1,792	1,788	1,628	1,825	1,828	1,864	1,833	20.2%
Electric Power	1,880	2,006	2,350	2,457	2,313	1,952	1,482	1,584	1,575	1,454	1,459	-22.4%
Industry	1,710	1,737	1,681	1,592	1,489	1,492	1,414	1,433	1,436	1,406	1,410	-17.6%
Agriculture	606	634	625	634	649	673	663	650	649	649	658	8.6%
Commercial	445	445	428	423	438	460	442	446	466	441	462	3.8%
Residential	346	368	388	371	356	351	357	365	387	361	354	2.5%
Total Gross Emissions	**6,513**	**6,843**	**7,375**	**7,444**	**7,038**	**6,716**	**5,986**	**6,302**	**6,341**	**6,175**	**6,177**	**-5.2%**

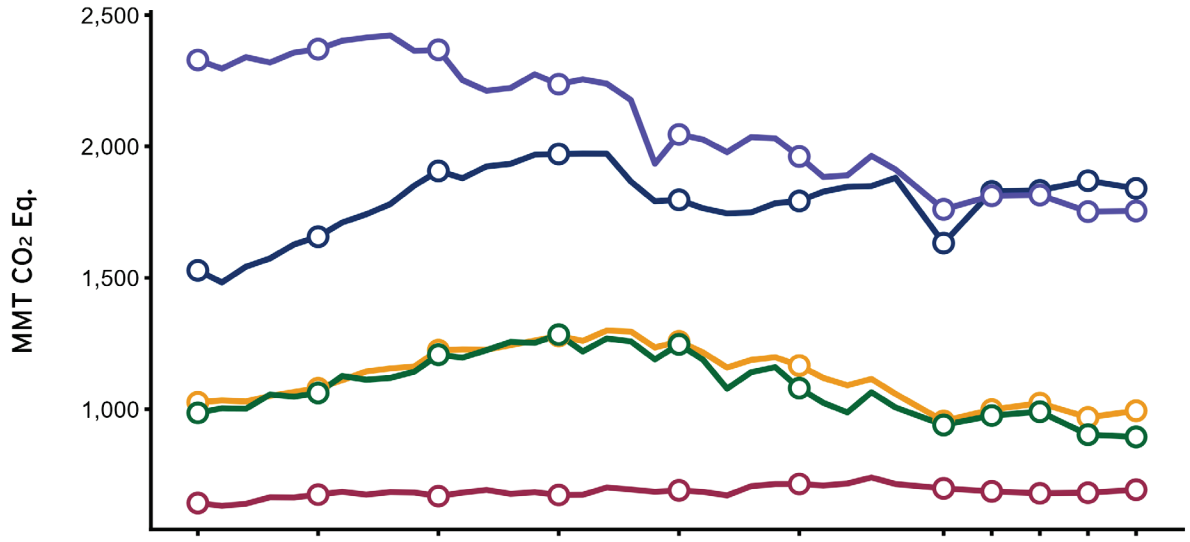
Note: Figure 2-10 excludes emissions from U.S. Territories and excludes emissions and removals from LULUCF sector.

Emissions and Removals by Economic Sector with Electricity Emission Distributed

When electricity emissions are allocated or distributed to the economic sector in which the electricity is ultimately consumed, the relative contribution to U.S. emissions and the trends show some significant differences.

As shown in Figure 2-11, industry consumes a significant amount of electricity to power processes and operate buildings and, as a result, is the largest economic sector for most of the time series. Electricity-related emissions attributable to industry decreased by 24.7 percent from 1990 to 2024, due to a shift away from energy-intensive industrial production, end-use efficiency improvements, and the overall drop in carbon intensity of electricity production in the United States.

Figure 2-11: Trends in Economic Sector Emissions with Electricity Distributed



	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Transportation	1,528	1,656	1,907	1,971	1,797	1,792	1,632	1,829	1,833	1,869	1,840	20.4%
Industry	2,329	2,370	2,368	2,237	2,045	1,962	1,760	1,812	1,815	1,752	1,754	-24.7%
Commercial	1,026	1,080	1,225	1,279	1,258	1,166	955	998	1,023	969	994	-3.1%
Residential	986	1,062	1,207	1,284	1,247	1,080	940	976	990	903	895	-9.3%
Agriculture	643	675	669	674	691	716	699	687	680	682	694	7.9%
Total Gross Emissions	**6,513**	**6,843**	**7,375**	**7,444**	**7,038**	**6,716**	**5,986**	**6,302**	**6,341**	**6,175**	**6,177**	**-5.1%**

Note: Figure 2-11 excludes emissions from U.S. Territories and excludes emissions and removals from LULUCF sector.

The overall trend in the transportation sector is basically the same as when electricity emissions are not included. Electricity use in transportation is increasing rapidly with the adoption of electric vehicles but is still a minor contributor to the total and trend.

As with industry, the level of electricity emissions attributable to the commercial and residential sectors is significant. In 2024, emissions from electricity distributed to the residential and commercial sectors made up 66 percent of the total direct and indirect emissions from those sectors. The relative importance of distributed electricity emissions has declined in recent years due to efficiency improvements and the lower carbon intensity of purchased electricity.

Trends in Focus

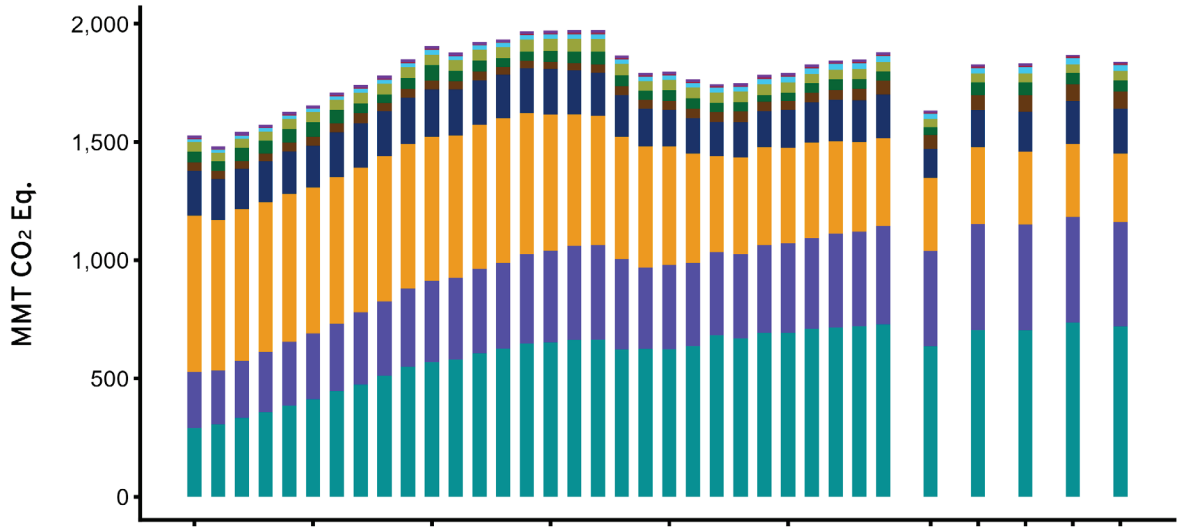
For this *GHGIA*, two key areas are discussed in more detail given their importance to understanding the long-term trend in total GHG emissions since 1990 and GHG emissions since 2005: transportation economic sector (all sources and all gases) and electricity sector (generation mix and fossil fuel CO_2 emissions).

Additionally, Box 2-1 presents trends in key economic and demographic indicators that can help illustrate how GHG emissions have changed in the context of other societal trends.

Transportation Economic Sector Emissions

Figure 2-12 shows emissions from the transportation economic sector, broken out by "mode" or vehicle type. In 1990, passenger cars made up by far the largest share of GHG emissions, but this share has declined almost every single year since then. In contrast, GHG emissions from light-duty trucks grew steadily over the period and now represent the largest share of emissions. This category includes some SUVs, pickup trucks, and minivans, which have grown significantly in popularity and typically have lower fuel economy than passenger cars due to their greater weight and engine size.

Figure 2-12: Trends in Transportation Sector by Mode



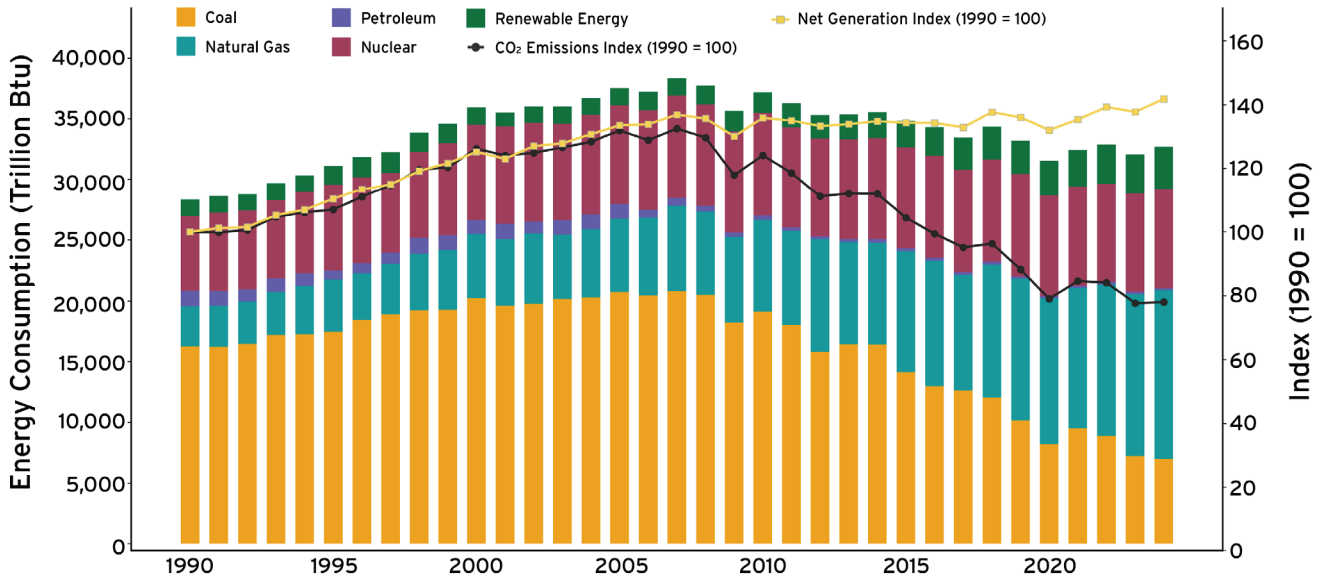
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024	90-24
Light-Duty Trucks	291	411	570	651	624	693	636	705	705	736	721	147.7%
Medium- and Heavy-Duty Trucks	237	279	344	390	357	378	403	448	447	447	442	86.9%
Passenger Cars	661	619	610	574	501	406	310	326	308	308	289	-56.4%
Aircraft	189	176	199	193	155	160	123	155	168	182	189	-0.1%
Pipelines	36	38	35	33	38	39	58	65	72	71	73	103.7%
Ships and Boats	47	59	66	45	45	34	32	54	53	47	48	3.0%
Rail	39	43	46	51	44	44	35	37	37	37	38	-2.8%
Buses	13	15	19	18	17	22	20	23	25	26	25	94.2%
Motorcycles	3	4	4	5	6	7	6	7	8	9	9	163.2%
Lubricants	12	11	12	10	10	11	8	8	9	6	6	-48.7%
Total Emissions	**1,528**	**1,656**	**1,906**	**1,971**	**1,797**	**1,792**	**1,632**	**1,829**	**1,833**	**1,869**	**1,840**	**20.4%**

Electricity Sector—Generation Mix and Fossil Fuel CO_2 Emissions

Figure 2-13 shows the changing fuel mix for electricity generation in the United States since 1990, along with the overall trend in electricity sector generation and fossil fuel CO_2 emissions. The correlation between declining coal use and emission reductions is clear, particularly since the 2005–2007 period. In 1990, coal generation represented 54 percent of the total CO_2 emissions in the United States. By 2024, that share had declined to 16 percent. Natural gas generation, which has grown from 11 percent to 42 percent of the total over the same period, is typically 55 percent less carbon intensive per unit of energy than coal.

Renewable energy generation in 1990 was modest at 11 percent and included mostly hydroelectric power. Over the last decade or so, other forms of renewable electricity such as solar and wind have increased significantly, and the overall share of renewables climbed to 23 percent by 2024.

Figure 2-13: Trends in Electricity Sector by Fuel Type



Box 2-1: Key Economic and Demographic Indicator Trends

Gross GHG emissions can be compared to other indices to illuminate how underlying economic and societal changes compare to emission trends. Comparative indices included in this chapter include:

- Aggregate energy use (the largest driver of CO_2 emissions);
- Energy use per capita;
- Emissions per unit of total gross domestic product; and
- Emissions per capita.

Table 2-1 provides time series data for these indices, normalized to 1990, and Figure 2-14 presents this information in chart form. Gross U.S. GHG emissions in the United States decreased at an average annual rate of 0.1 percent. This growth rate is slightly slower than that for total energy use, overall gross domestic product (GDP) and national population.

Around the year 2005, GHG emissions, total energy use, and associated fossil fuel consumption began to peak. Since 2005, emissions have decreased at an average annual rate of 0.9 percent, while GDP and national population generally continued to increase. Energy use has decreased slightly, with 2020 being an exception due to the impact of the COVID-19 pandemic.

Indicator	1990	2005	2020	2021	2022	2023	2024	Avg. Annual % Change Since 1990[a]	Avg. Annual % Change Since 2005[a]
Greenhouse Gas Emissions[b]	100	115	92	97	97	95	95	−0.1%	−0.9%
Energy Use[c]	100	119	108	113	116	114	114	0.4%	−0.2%
GDP[d]	100	159	202	214	220	226	232	2.5%	2.0%
Population[e]	100	118	132	132	133	134	136	0.9%	0.7%

[a] Average annual growth rate.

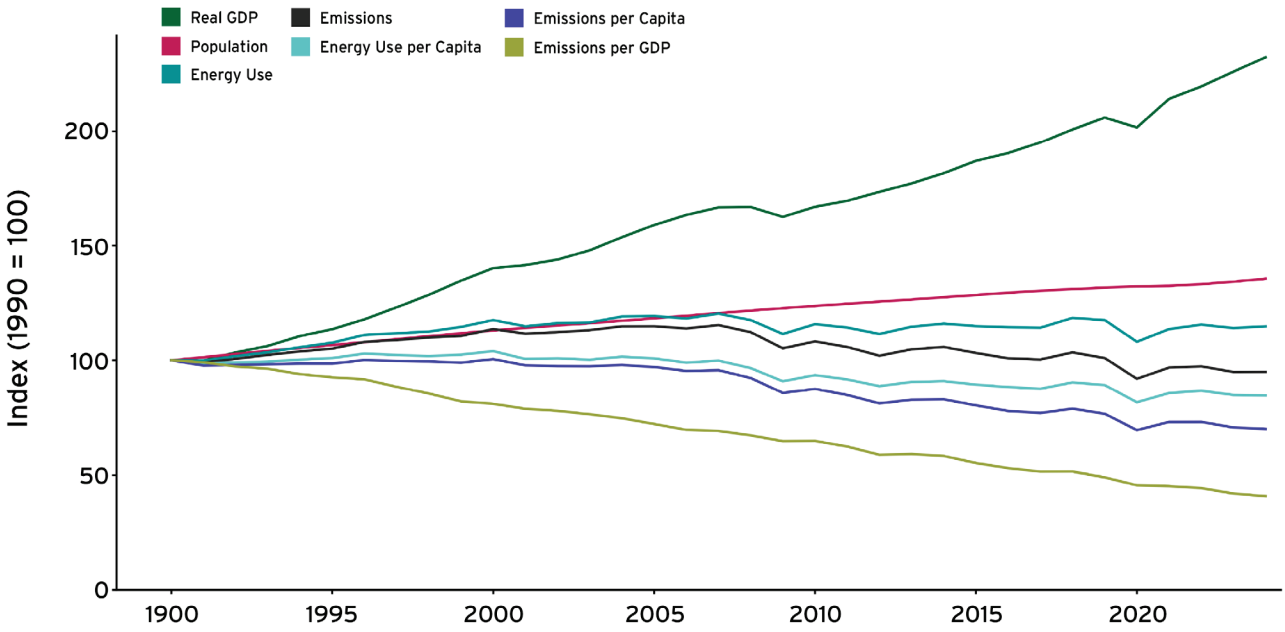
[b] Gross total GWP-weighted values.

[c] Energy-content-weighted values (EIA, 2026).

[d] GDP in chained 2017 dollars (BEA, 2026).

[e] U.S. Census Bureau (2024, 2025).

Figure 2-14: Key Economic and Demographic Indicator Trends



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