United States Environmental Protection Agency

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Greenhouse Gas Emissions

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Overview of Greenhouse Gases

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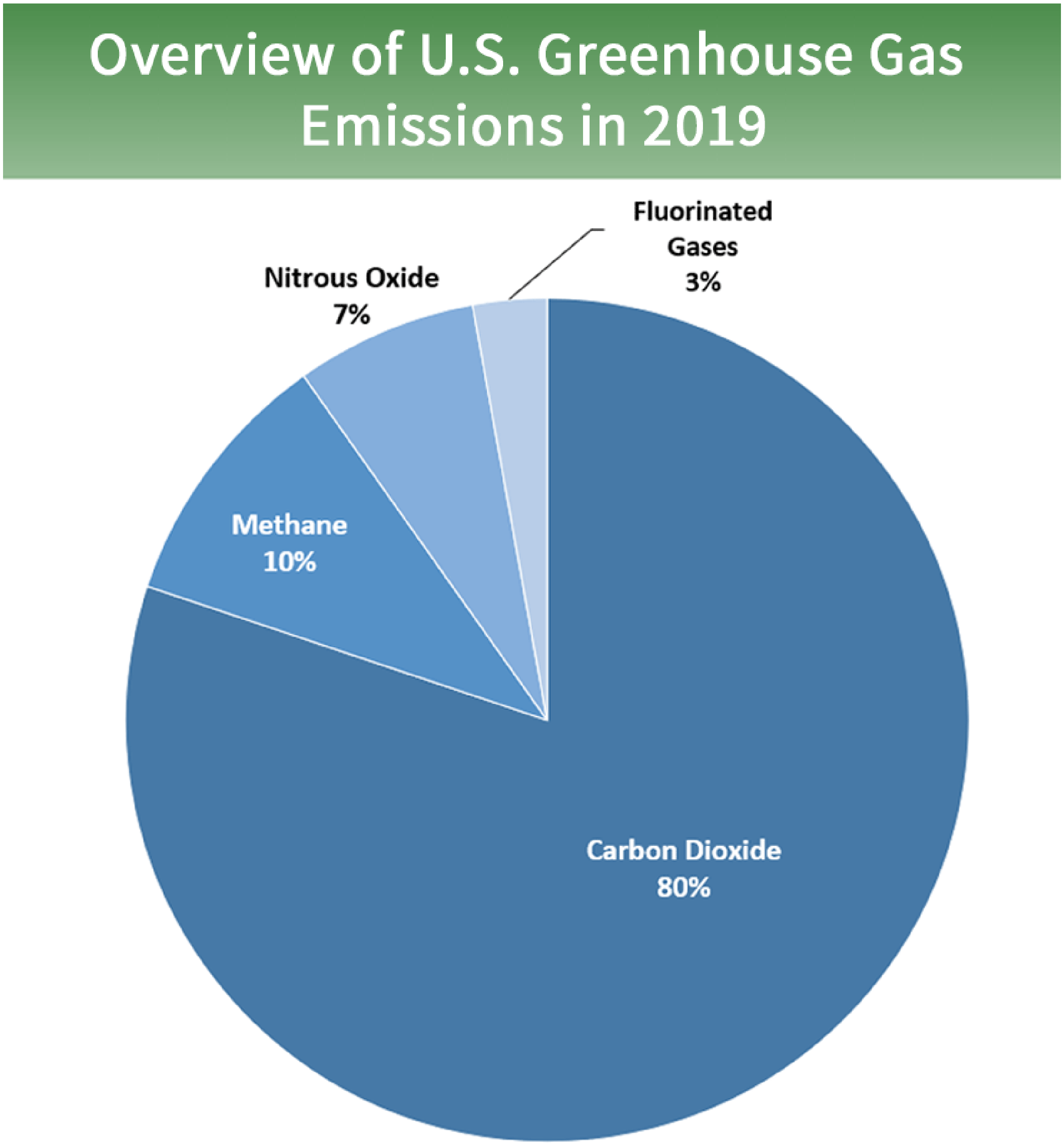

Total U.S. Emissions in 2019 = 6,558 Million Metric Tons of CO2 equivalent (excludes land sector). Percentages may not add up to 100% due to independent rounding.

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Gases that trap heat in the atmosphere are called greenhouse gases. This section provides information on emissions and removals of the main greenhouse gases to and from the atmosphere. For more information on the other climate forcers, such as black carbon <https://www3.epa.gov/airquality/blackcarbon/>, please visit the Climate Change Indicators: Climate Forcing <https://epa.gov/climate-indicators/climate-change-indicators-climate-forcing> page.

- **Carbon dioxide (CO_2)**: Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4)**: Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous oxide (N_2O)**: Nitrous oxide is emitted during agricultural, land use, industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.
- **Fluorinated gases**: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances <https://epa.gov/ozone-layer-protection> (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> gases ("High GWP gases").

Each gas's effect on climate change depends on three main factors:

How much is in the atmosphere?

> **Concentration, or abundance**, is the amount of a particular gas in the air. Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere. Greenhouse gas concentrations are measured in parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car). To learn more about the increasing concentrations of greenhouse gases in the atmosphere, visit the Climate Change Indicators: Atmospheric Concentrations of Greenhouse Gases <https://epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases> page.

How long do they stay in the atmosphere?

> Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

How strongly do they impact the atmosphere?

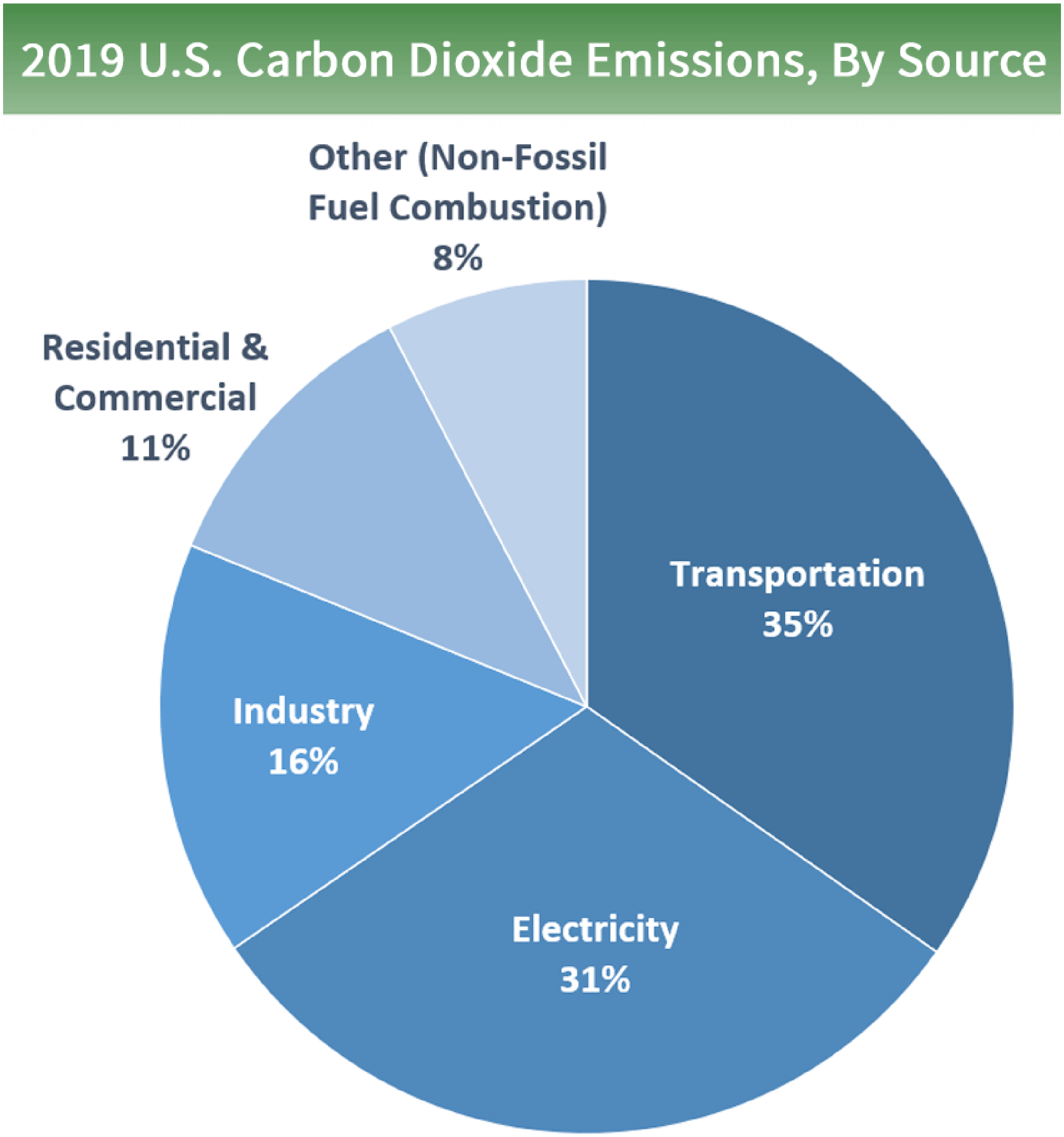
> Some gases are more effective than others at making the planet warmer and "thickening the Earth's blanket."
>
> For each greenhouse gas, a Global Warming Potential (GWP) <https://epa.gov/ghgemissions/understanding-global-warming-potentials> has been calculated to reflect how long it remains in the atmosphere, on average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy, per pound, than gases with a lower GWP, and thus contribute more to warming Earth.

Note: All emission estimates are from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019 <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

Carbon Dioxide Emissions

Properties of Carbon Dioxide
Chemical Formula: CO_2 **Lifetime in Atmosphere**: See below[1] **Global Warming Potential** <https://epa.gov/ghgemissions/understanding-global-warming-potentials> **(100-year)**: 1

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2019, CO_2 accounted for about 80 percent of all U.S. greenhouse gas emissions from human activities. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle–both by adding more CO_2 to the atmosphere, and by influencing the ability of natural sinks, like forests and soils, to remove and store CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution.[2]



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> (excludes land sector).*

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The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2. The main sources of CO_2 emissions in the United States are described below.

- **Transportation** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation>. The combustion of fossil fuels such as gasoline and diesel to transport people and goods was the largest source of CO_2 emissions in 2019, accounting for about 35 percent of total U.S. CO_2 emissions and 28 percent of total U.S. greenhouse gas emissions. This category includes transportation sources such as highway and passenger vehicles, air travel, marine transportation, and rail.
- **Electricity** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#electricity>. Electricity is a significant source of energy in the United States and is used to power homes, business, and industry. In 2019, the combustion of fossil fuels to generate electricity was the second largest source of CO_2 emissions in the nation, accounting for about 31 percent of total U.S. CO_2 emissions and 24 percent of total U.S. greenhouse gas emissions. The types of fossil fuel used to generate electricity emit different amounts of CO_2. To produce a given amount of electricity, burning coal will produce more CO_2 than natural gas or oil.
- **Industry** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry>. Many industrial processes emit CO_2 through fossil fuel consumption. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, and examples include the production of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Fossil fuel combustion from various industrial processes accounted for about 16 percent of total U.S. CO_2 emissions and 13 percent of total U.S. greenhouse gas emissions in 2019. Many industrial processes also use electricity and therefore indirectly result in CO_2 emissions from electricity generation.

Carbon dioxide is constantly being exchanged among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, plants, and animals. However, emissions and removal of CO_2 by these natural processes tend to balance, absent anthropogenic impacts. Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere.

In the United States, since 1990, the management of forests and other land (e.g., cropland, grasslands, etc.) has acted as a net sink of CO_2, which means that more CO_2 is removed from the atmosphere, and stored in plants and trees, than is emitted. This carbon sink offset is about 12 percent of total emissions in 2019 and is discussed in more detail in the Land Use, Land-Use Change, and Forestry <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry> section.

To find out more about the role of CO_2 in warming the atmosphere and its sources, visit the Climate Change Indicators <https://epa.gov/climate-indicators> page.

Emissions and Trends

Carbon dioxide emissions in the United States increased by about 3 percent between 1990 and 2019. Since the combustion of fossil fuel is the largest source of greenhouse gas emissions in the United States, changes in emissions from fossil fuel combustion have historically been the dominant factor affecting total U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population growth, economic growth, changing energy prices, new technologies, changing behavior, and seasonal temperatures. Between 1990 and 2019, the increase in CO_2 emissions corresponded with increased energy use by an expanding economy and population, including overall growth in emissions from increased demand for travel.

Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

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Reducing Carbon Dioxide Emissions

The most effective way to reduce CO_2 emissions is to reduce fossil fuel consumption. Many strategies for reducing CO_2 emissions from energy are cross-cutting and apply to homes, businesses, industry, and transportation.

EPA is taking common sense regulatory actions to reduce greenhouse gas emissions.

- Learn about EPA's motor vehicle standards <https://epa.gov/vehicles-and-engines>.

Examples of Reduction Opportunities for Carbon Dioxide

Strategy	Examples of How Emissions Can be Reduced
Energy Efficiency	Improving the insulation of buildings, traveling in more fuel-efficient vehicles, and using more efficient electrical appliances are all ways to reduce energy use, and thus CO_2 emissions. • See EPA's ENERGY STAR® program <https://www.energystar.gov/> for more information on energy-efficient appliances. • See EPA's and DOE's fueleconomy.gov site <https://www.fueleconomy.gov/> for more information on fuel-efficient vehicles. • Learn about EPA's motor vehicle standards <https://epa.gov/vehicles-and-engines> that improve vehicle efficiency and save drivers money.
Energy Conservation	Reducing personal energy use by turning off lights and electronics when not in use reduces electricity demand. Reducing distance traveled in vehicles reduces petroleum consumption. Both are ways to reduce energy CO_2 emissions through conservation. Learn more about What You Can Do at Home, at School, in the Office <https://www3.epa.gov/climatechange//kids/solutions/actions/index.html>, and on the Road <https://epa.gov/transportation-air-pollution-and-climate-change/what-you-can-do-reduce-pollution-vehicles-and-engines> to save energy and reduce your carbon footprint.
Fuel Switching	Producing more energy from renewable sources and using fuels with lower carbon contents are ways to reduce carbon emissions.

Strategy	Examples of How Emissions Can be Reduced
Carbon Capture and Sequestration (CCS)	Carbon dioxide capture and sequestration is a set of technologies that can potentially greatly reduce CO_2 emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of CO_2. For example, capturing CO_2 from the stacks of a coal-fired power plant before it enters the atmosphere, transporting the CO_2 via pipeline, and injecting the CO_2 deep underground at a carefully selected and suitable subsurface geologic formation, such as a nearby abandoned oil field, where it is securely stored. Learn more about CCS <https://epa.gov/uic/class-vi-wells-used-geologic-sequestration-co2>.
Changes in Uses of Land and Land Management Practices	Learn more about Land Use, Land Use Change and Forestry Sector. <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry>

[1] Atmospheric CO_2 is part of the global carbon cycle, and therefore its fate is a complex function of geochemical and biological processes. Some of the excess carbon dioxide will be absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.

[2]IPCC (2013). Climate Change 2013: The Physical Science Basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1585 pp.

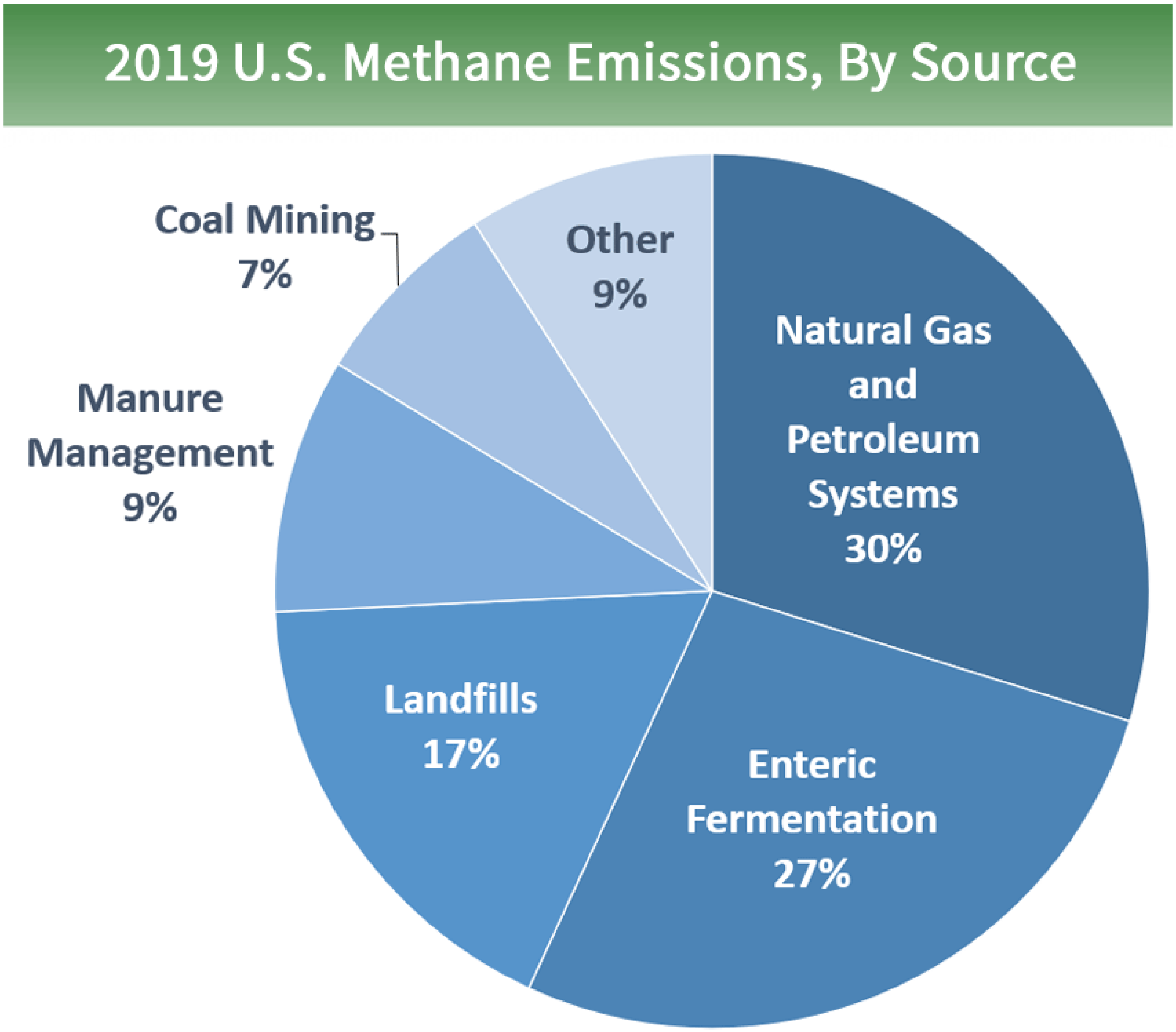
Methane Emissions

Properties of Methane

Chemical Formula: CH_4
Lifetime in Atmosphere: 12 years
Global Warming Potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> **(100-year)**: 25[1]

In 2019, methane (CH_4) accounted for about 10 percent of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. Methane is also emitted by natural sources such as natural wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, the comparative impact of CH_4 is 25 times greater than CO_2 over a 100-year period.[1]

Globally, 50-65 percent of total CH_4 emissions come from human activities.[2, 3] Methane is emitted from energy, industry, agriculture, land use, and waste management activities, described below.



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> (excludes land sector).*

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- **Agriculture** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#agriculture>. Domestic livestock such as cattle, swine, sheep, and goats produce CH_4 as part of their normal digestive process. Also, when animal manure is stored or managed in lagoons or holding tanks, CH_4 is produced. Because humans raise these animals for food and other products, the emissions are considered human-related. When livestock and manure emissions are combined, the Agriculture sector is the largest source of CH_4 emissions in the United States. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> Agriculture chapter. While not shown and less significant, emissions of CH_4 also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry> sector (e.g. forest and grassland fires, decomposition of organic matter in coastal wetlands, etc.).
- **Energy and Industry** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry>. Natural gas and petroleum systems are the second largest source of CH_4 emissions in the United States. Methane is the primary component of natural gas. Methane is emitted to the atmosphere during the production, processing, storage, transmission, and distribution of natural gas and the production, refinement, transportation, and storage of crude oil. Coal mining is also a source of CH_4 emissions. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> sections on Natural Gas Systems and Petroleum Systems.
- **Waste from Homes and Businesses** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#commercial-and-residential>**.** Methane is generated in landfills as waste decomposes and in the treatment of wastewater. Landfills are the third-largest source of CH_4 emissions in the United States. Methane is also generated from domestic and industrial wastewater treatment and from composting and anerobic digestion. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> Waste chapter.

Methane is also emitted from a number of natural sources. Natural wetlands are the largest source, emitting CH_4 from bacteria that decompose organic materials in the absence of oxygen. Smaller sources include termites, oceans, sediments, volcanoes, and wildfires.

To find out more about the role of CH_4 in warming the atmosphere and its sources, visit the Climate Change Indicators <https://epa.gov/climate-indicators> page.

Emissions and Trends

Methane emissions in the United States decreased by 15 percent between 1990 and 2019. During this time period, emissions increased from sources associated with agricultural activities, while emissions decreased from sources associated with landfills, coal mining, and from natural gas and petroleum systems.

Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>. These estimates use a global warming potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> for methane of 25, based on reporting requirements under the United Nations Framework Convention on Climate Change.

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Reducing Methane Emissions

There are a number of ways to reduce CH_4 emissions. Some examples are discussed below. EPA has a series of voluntary programs for reducing CH_4 emissions, in addition to regulatory initiatives <https://epa.gov/controlling-air-pollution-oil-and-natural-gas-industry>. EPA also supports the Global Methane Initiative , an international partnership encouraging global methane reduction strategies.

Examples of Reduction Opportunities for Methane

Emissions Source	How Emissions Can be Reduced
Industry	Upgrading the equipment used to produce, store, and transport oil and natural gas can reduce many of the leaks that contribute to CH_4 emissions. Methane from coal mines can also be captured and used for energy. Learn more about the EPA's Natural Gas STAR Program <https://epa.gov/natural-gas-star-program> and Coalbed Methane Outreach Program <https://epa.gov/cmop>.
Agriculture	Methane from manure management practices can be reduced and captured by altering manure management strategies. Additionally, modifications to animal feeding practices may reduce emissions from enteric fermentation. Learn more about improved manure management practices at EPA's AgSTAR Program <https://epa.gov/agstar>.
Waste from Homes and Businesses	Because CH_4 emissions from landfill gas are a major source of CH_4 emissions in the United States, emission controls that capture landfill CH_4 are an effective reduction strategy. Learn more about these opportunities and the EPA's Landfill Methane Outreach Program <https://epa.gov/lmop>.

References

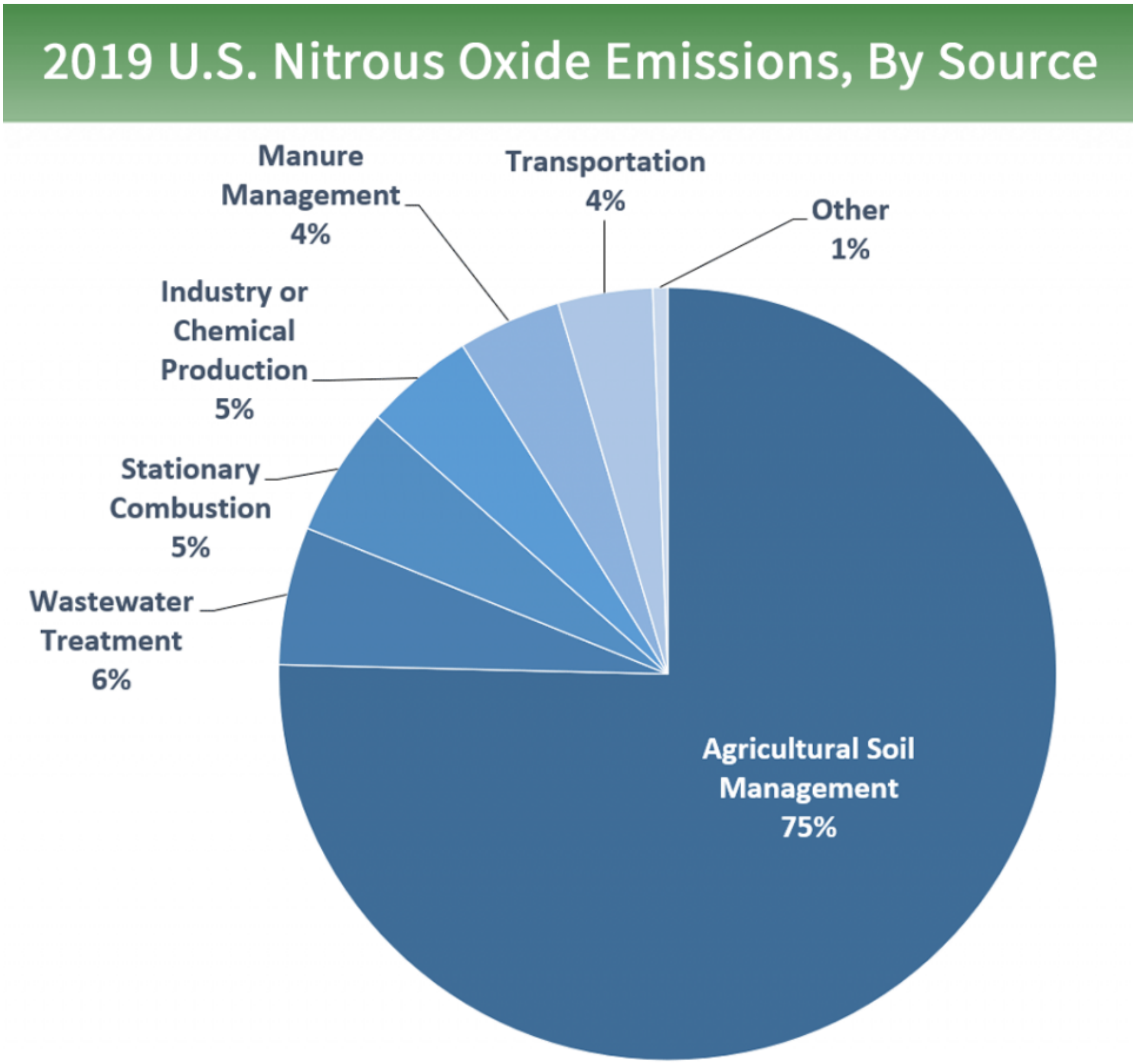
[1]IPCC (2007). *Climate Change 2007: The Physical Science Basis* . *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press. Cambridge, United Kingdom 996 pp.
[2]IPCC (2013). Climate Change 2013: The Physical Science Basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1585 pp.
[3]The Global Carbon Project (2019).

Nitrous Oxide Emissions

Properties of Nitrous Oxide

Chemical Formula: N_2O
Lifetime in Atmosphere: 114 years
Global Warming Potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> **(100-year)**: 298[1]

In 2019, nitrous oxide (N_2O) accounted for about 7 percent of all U.S. greenhouse gas emissions from human activities. Human activities such as agriculture, fuel combustion, wastewater management, and industrial processes are increasing the amount of N_2O in the atmosphere. Nitrous oxide is also naturally present in the atmosphere as part of the Earth's nitrogen cycle, and has a variety of natural sources. Nitrous oxide molecules stay in the atmosphere for an average of 114 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of N_2O on warming the atmosphere is almost 300 times that of 1 pound of carbon dioxide.[1]



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> (excludes land sector).*

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Globally, about 40 percent of total N_2O emissions come from human activities.[2] Nitrous oxide is emitted from agriculture, land use, transportation, industry, and other activities, described below.

- **Agriculture** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#agriculture>**.** Nitrous oxide can result from various agricultural soil management activities, such as application of synthetic and organic fertilizers and other cropping practices, the management of manure, or burning of agricultural residues. Agricultural soil management is the largest source of N_2O emissions in the United States, accounting for about 75 percent of total U.S. N_2O emissions in 2019. While not shown and less significant, emissions of N_2O also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry> sector (e.g. forest and grassland fires, application of synthetic nitrogen fertilizers to urban soils (e.g., lawns, golf courses) and forest lands, etc.).
- **Fuel Combustion** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation>**.** Nitrous oxide is emitted when fuels are burned. The amount of N_2O emitted from burning fuels depends on the type of fuel and combustion technology, maintenance, and operating practices.
- **Industry** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry>**.** Nitrous oxide is generated as a byproduct during the production of chemicals such as nitric acid, which is used to make synthetic commercial fertilizer, and in the production of adipic acid, which is used to make fibers, like nylon, and other synthetic products.
- **Waste.** Nitrous oxide is also generated from treatment of domestic wastewater during nitrification and denitrification of the nitrogen present, usually in the form of urea, ammonia, and proteins.

Nitrous oxide emissions occur naturally through many sources associated with the nitrogen cycle, which is the natural circulation of nitrogen among the atmosphere, plants, animals, and microorganisms that live in soil and water. Nitrogen takes on a variety of chemical forms throughout the nitrogen cycle, including N_2O. Natural emissions of N_2O are mainly from bacteria breaking down nitrogen in soils and the oceans. Nitrous oxide is removed from the atmosphere when it is absorbed by certain types of bacteria or destroyed by ultraviolet radiation or chemical reactions.

To find out more about the sources of N_2O and its role in warming the atmosphere, visit the Climate Change Indicators <https://epa.gov/climate-indicators> page.

Emissions and Trends

Nitrous oxide emissions in the United States have remained relatively flat between 1990 and 2019. Nitrous oxide emissions from mobile combustion decreased by 60 percent from 1990 to 2019 as a result of emission control standards for on-road vehicles. Nitrous oxide emissions from agricultural soils have varied during this period and were about 9 percent higher in 2019 than in 1990, primarily driven by increasing use of nitrogen fertilizers.

Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

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Reducing Nitrous Oxide Emissions

There are a number of ways to reduce emissions of N_2O, discussed below.

Examples of Reduction Opportunities for Nitrous Oxide Emissions

Emissions Source	Examples of How Emissions Can be Reduced
Agriculture	The application of nitrogen fertilizers accounts for the majority of N_2O emissions in the United States. Emissions can be reduced by reducing nitrogen-based fertilizer applications and applying these fertilizers more efficiently,[3] as well as modifying a farm's manure management practices.

Emissions Source	Examples of How Emissions Can be Reduced
Fuel Combustion	• Nitrous oxide is a byproduct of fuel combustion, so reducing fuel consumption in motor vehicles and secondary sources can reduce emissions. • Additionally, the introduction of pollution control technologies (e.g., catalytic converters to reduce exhaust pollutants from passenger cars) can also reduce emissions of N_2O.
Industry	• Nitrous oxide is generally emitted from industry through fossil fuel combustion, so technological upgrades and fuel switching are effective ways to reduce industry emissions of N_2O. • Production of adipic acid results in N_2O emissions that can be reduced through technological upgrades.

References

[1] IPCC (2007) *Climate Change 2007: The Physical Science Basis* . *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press. Cambridge, United Kingdom 996 pp.

[2]IPCC (2013). Climate Change 2013: The Physical Science Basis . *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1585 pp.

[3]EPA (2005). *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*. U.S. Environmental Protection Agency, Washington, DC, USA.

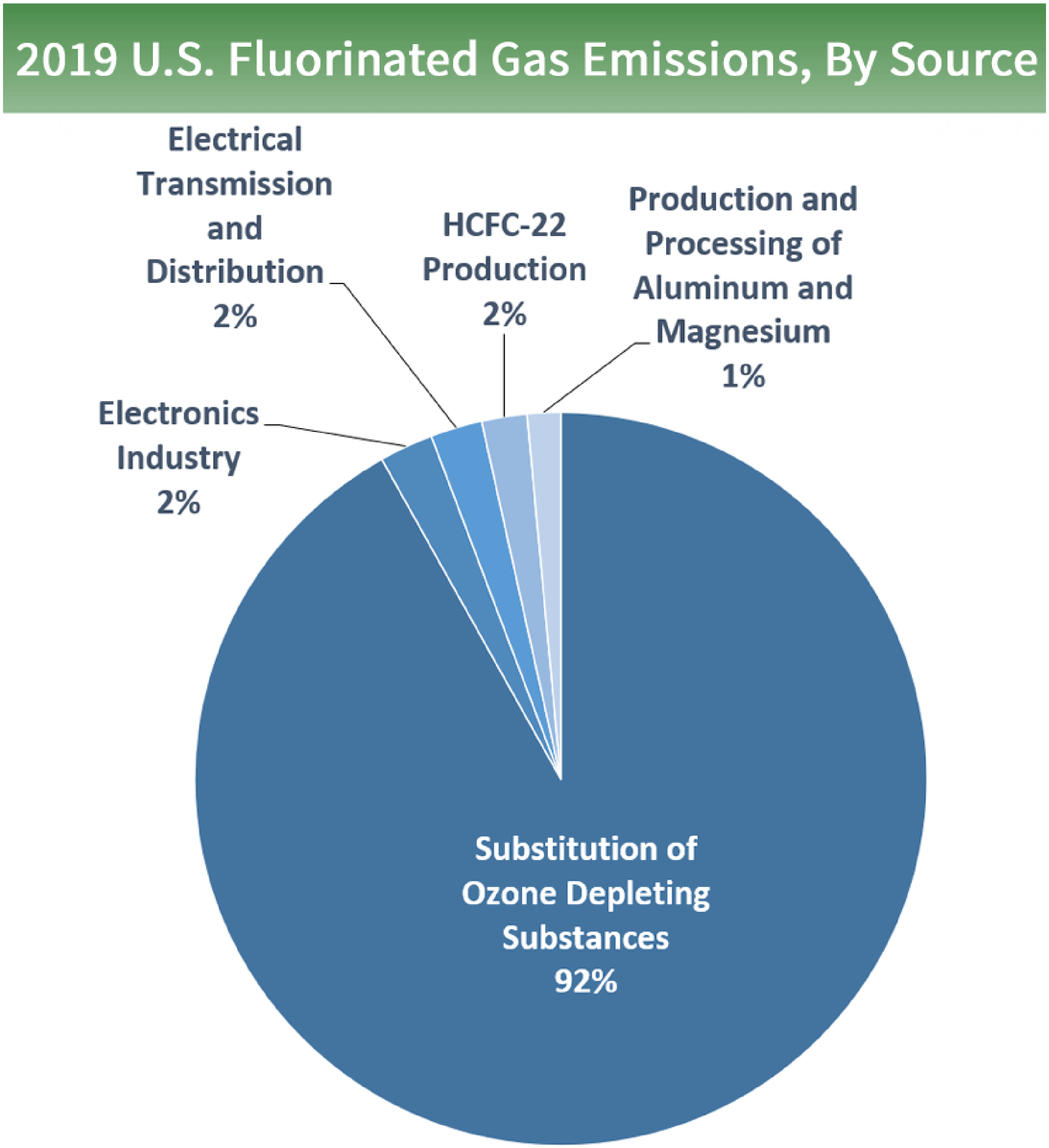
Emissions of Fluorinated Gases

Properties of F-gases

Chemical Formulas:
HFCs, PFCs, NF_3, SF_6
Lifetime in Atmosphere:
HFCs: up to 270 years
PFCs: 2,600–50,000 years
NF_3: 740 years
SF_6: 3,200 years
Global Warming Potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> **(100-year)**:[1]
HFCs: up to 14,800
PFCs: up to 12,200
NF_3: 17,200
SF_6: 22,800

Unlike many other greenhouse gases, fluorinated gases have no natural sources and only come from human-related activities. They are emitted through their use as substitutes for ozone-depleting substances (e.g., as refrigerants) and through a variety of industrial processes such as aluminum and semiconductor manufacturing. Many fluorinated gases have very high global warming potentials (GWPs) relative to other greenhouse gases, so small atmospheric concentrations can have disproportionately large effects on global temperatures. They can also have long atmospheric lifetimes—in some cases, lasting thousands of years. Like other long-lived greenhouse gases, most fluorinated gases are well-mixed in the atmosphere, spreading around the world after they are emitted. Many fluorinated gases are removed from the atmosphere only when they are destroyed by sunlight in the far upper atmosphere. In general, fluorinated gases are the most potent and longest lasting type of greenhouse gases emitted by human activities.

There are four main categories of fluorinated gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The largest sources of fluorinated gas emissions are described below.



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

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- **Substitution for Ozone-Depleting Substances.** Hydrofluorocarbons are used as refrigerants, aerosol propellants, foam blowing agents, solvents, and fire retardants. The major emissions source of these compounds is their use as refrigerants—for example, in air conditioning systems in both vehicles and buildings. These chemicals were developed as a replacement for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) because they do not deplete the stratospheric ozone layer. Chlorofluorocarbons and HCFCs are being phased out under an international agreement, called the Montreal Protocol. HFCs are potent greenhouse gases with high GWPs, and they are released into the atmosphere during manufacturing processes and through leaks, servicing, and disposal of equipment in which they are used. Newly developed hydrofluoroolefins (HFOs) are a subset of HFCs and are characterized by short atmospheric lifetimes and lower GWPs. HFOs are currently being introduced as refrigerants, aerosol propellants and foam blowing agents. The American Innovation and Manufacturing (AIM) Act <https://epa.gov/climate-hfcs-reduction/aim-act> of 2020 directs EPA to address HFCs by providing new authorities in three main areas: to phase down the production and consumption of listed HFCs in the United States by 85 percent over the next 15 years, manage these HFCs and their substitutes, and facilitate the transition to next-generation technologies that do not rely on HFCs.
- **Industry.** Perfluorocarbons are produced as a byproduct of aluminum production and are used in the manufacturing of semiconductors. PFCs generally have long atmospheric lifetimes and GWPs near 10,000. Sulfur hexafluoride is used in magnesium processing and semiconductor manufacturing, as well as a tracer gas for leak detection. HFC-23 is produced as a byproduct of HCFC-22 production and is used in semiconductor manufacturing.
- **Transmission and Distribution of Electricity.** Sulfur hexafluoride is used as an insulating gas in electrical transmission equipment, including circuit breakers. The GWP of SF_6 is 22,800, making it the most potent greenhouse gas that the Intergovernmental Panel on Climate Change has evaluated.

To find out more about the role of fluorinated gases in warming the atmosphere and their sources, visit the Fluorinated Greenhouse Gas Emissions <https://epa.gov/ghgreporting/fluorinated-greenhouse-gas-emissions-and-supplies-reported-ghgrp> page.

Emissions and Trends

Overall, fluorinated gas emissions in the United States have increased by about 86 percent between 1990 and 2019. This increase has been driven by a 275 percent increase in emissions of hydrofluorocarbons (HFCs) since 1990, as they have been widely used as a substitute for ozone-depleting substances. Emissions of perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) have actually declined during this time due to emission reduction efforts in the aluminum production industry (PFCs) and the electricity transmission and distribution industry (SF_6).

Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

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Reducing Fluorinated Gas Emissions

Because most fluorinated gases have a very long atmospheric lifetime, it will take many years to see a noticeable decline in current concentrations. However, there are a number of ways to reduce emissions of fluorinated gases, described below.

Examples of Reduction Opportunities for Fluorinated Gases

Emissions Source	Examples of How Emissions Can be Reduced

Emissions Source	Examples of How Emissions Can be Reduced
Substitution of Ozone-Depleting Substances in Homes and Businesses	Refrigerants used by businesses and residences emit fluorinated gases. Emissions can be reduced by better handling of these gases and use of substitutes with lower global warming potentials and other technological improvements. Visit EPA's Ozone Layer Protection site <https://epa.gov/ozone-layer-protection> to learn more about reduction opportunities in this sector.
Industry	Industrial users of fluorinated gases can reduce emissions by adopting fluorinated gas recycling and destruction processes, optimizing production to minimize emissions, and replacing these gases with alternatives. EPA has the following resources to manage these gases in the Industry sector: • Voluntary Aluminum Industrial Partnership <https://epa.gov/node/136025> • The SF_6 Emission Reduction Partnership for the Magnesium Industry <https://epa.gov/f-gas-partnership-programs/magnesium-industry> • The PFC Reduction/Climate Partnership for the Semiconductor Industry <https://epa.gov/f-gas-partnership-programs/semiconductor-industry>
Electricity Transmission and Distribution	Sulfur hexafluoride is an extremely potent greenhouse gas that is used for several purposes when transmitting electricity through the power grid. EPA is working with industry to reduce emissions through the SF_6 Emission Reduction Partnership for Electric Power Systems <https://epa.gov/eps-partnership>, which promotes leak detection and repair, use of recycling equipment, and employee training.

Emissions Source	Examples of How Emissions Can be Reduced
Transportation	Hydrofluorocarbons (HFCs) are released through the leakage of refrigerants used in vehicle air-conditioning systems. Leakage can be reduced through better system components, and through the use of alternative refrigerants with lower global warming potentials than those presently used. EPA's light-duty and heavy-duty vehicle standards <https://epa.gov/vehicles-and-engines> provided incentives for manufacturers to produce vehicles with lower HFC emissions.

References

[1]IPCC (2007) Climate Change 2007: The Physical Science Basis . Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press. Cambridge, United Kingdom 996 pp.

GHG Emissions Home <https://epa.gov/ghgemissions>

Overview of Greenhouse Gases

Sources of GHG Emissions <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions>

Global Emissions <https://epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

National Emissions <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>

Facility-Level Emissions <https://epa.gov/ghgreporting>

Carbon Footprint Calculator <https://epa.gov/ghgemissions/household-carbon-footprint-calculator>

GHG Equivalencies Calculator <http://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>

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