Greenhouse Gases

The Greenhouse Effect

The greenhouse effect is a natural phenomenon that insulates the Earth from the cold of space. As incoming solar radiation is absorbed and re-emitted from the Earth's surface as infrared energy, greenhouse gases (GHGs) in the atmosphere prevent some of this heat from escaping into space, instead reflecting the energy back to further warm the surface.[1] The greenhouse effect was first described in the 1820s, and GHGs and sources (e.g., burning coal) responsible for amplifying this effect were identified later in the 1800s.[2] Anthropogenic (human-caused) GHG emissions are modifying the Earth's energy balance between incoming solar radiation and the heat released into space, amplifying the greenhouse effect and resulting in climate change.[1]

Greenhouse Gases

- There are ten primary GHGs; of these, water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are naturally occurring. Perfluorocarbons (CF_6, C_2F_6), hydrofluorocarbons (CHF_3, CF_3CH_2F, CH_3CHF_2), and sulfur hexafluoride (SF_6) are only present in the atmosphere due to industrial processes.[4]
- Water vapor is the most abundant GHG in the atmosphere. Its concentration depends on temperature and meteorological conditions and not directly on human activities.[1]
- Global Warming Potentials (GWPs) indicate the relative effectiveness of GHGs in trapping the Earth's heat over a certain time horizon. CO_2, the primary anthropogenic GHG, is used as the reference gas and has a GWP of one. The 100-year GWP of N_2O is 273, indicating that its radiative effect on a mass basis is 273 times that of CO_2 over 100 years.[1]
- GHG emissions are discussed in terms of mass of carbon dioxide equivalents (CO_2e), which are calculated by multiplying the mass of emissions by the GWP of the gas.[5]

The Main Greenhouse Gases[1,3]

Compound	Pre-industry Concentration	Concentration in 2019	Atmospheric Lifetime (years)	Main Human Activity Source	GWP**
Carbon dioxide (CO_2)	278 ppm	417.9 ppm*	Variable	Fossil fuels, cement production, land use change	1
Methane (CH_4)	729 ppb	1,923 ppb*	12	Fossil fuels, rice paddies, waste dumps, livestock	30 (fossil fuel), 27 (non-fossil fuel)
Nitrous Oxide (N_2O)	270 ppb	335.8 ppb*	109	Fertilizers, combustion industrial processes	273
HFC-134a (CF_3CH_2F)	0 ppt	108 ppt	14	Refrigerant	1,526
HFC-32 (CH_2F_2)	0 ppt	20 ppt	5	Refrigerant	771
CFC-11 (CCl_3F)	0 ppt	226 ppt	52	Refrigerant	6,226
PFC-14 (CF_4)	34 ppt	86 ppt	50,000	Aluminum production	7,380
SF_6	0 ppt	9.95 ppt	3,200	Electrical insulation	25,200

*Concentration in 2022; 1ppm = 1,000 ppb = 1,000,000 ppt; **GWP = 100-year global warming potential

Atmospheric Greenhouse Gas Emissions

- Since 1750, atmospheric concentrations of CO_2, CH_4, and N_2O increased by 150%, 264%, and 124% respectively,[3] to levels that are unprecedented in the past 800,000 years.[1]
- Before the Industrial Revolution, the concentration of CO_2 remained around 290 parts per million (ppm) by volume.[1] By May 2024, the global monthly average concentration had increased to 426.9 ppm.[6]

Sources of Greenhouse Gas Emissions

- The largest source of CO_2 emitted by human activities in the U.S. is fossil fuel combustion, primarily from transporatation and power generation. Iron and steel production, cement production, and NG systems are other significant sources of CO_2 emissions.[5]
- CH_4 and N_2O are emitted from both natural and anthropogenic sources. Domestic livestock, landfills, and natural gas systems are the primary anthropogenic sources of CH_4.[5]
- Agricultural soil management (fertilizer) produces 75% of anthropogenic N_2O in the U.S. Other major sources include mobile and stationary combustion and wastewater treatment.[5]
- Hydrofluorocarbons (HFCs) are used in refrigeration, cooling, and as solvents in place of ozone-depleting chlorofluorocarbons (CFCs).[7]

Emissions and Trends

Global

- In 2022, global anthropogenic GHG emissions were 53.8 Gt CO_2e, an increase of 62% since 1990.[8]
- Average annual GHG emissions were 56 Gt CO_2e from 2010-19. This is the highest decadal average on record and almost 10 Gt CO_2e more than the previous decade (2000-09).[9]
- Fossil fuel combustion is responsible for a majority (73%) of global anthropogenic GHG emissions.[10] In 2023, global energy-related CO_2 emissions reached a record high of 37.2 Gt, up 52% since 2000.[11] Based on current trends, global energy-related CO_2 emissions are anticipated to increase by 15% from 2022 to 2050.[12]
- F-gases, a family of gases containing fluorine (e.g. hydrofluorocarbons (HFCs)), are the fastest growing category of GHG. In 2022, global F-gas emissions grew by 5.5%, followed by CH_4 at 1.8% and N_2O at 0.9%.[13]
- Since 2005, China has surpassed the U.S. as the largest source of annual anthropogenic CO_2 emissions.[14] In 2022, per capita CO_2 emissions in China were double the global average, while those in the U.S. were triple the global average.[8]
- There is a huge emissions difference between high-income and low-income populations. Globally, 10% of the population with the highest income generated 48% of emissions, with

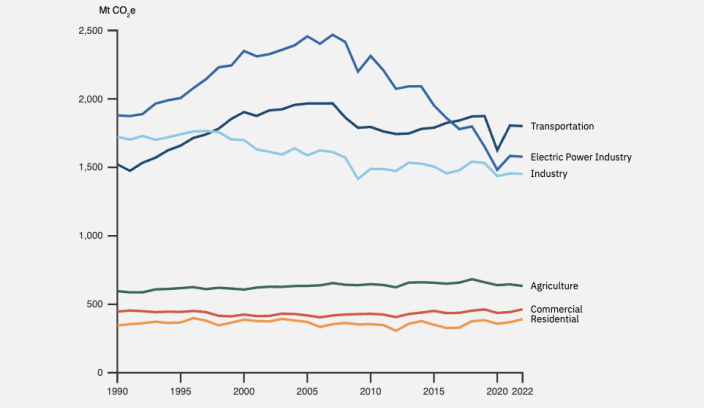
two thirds of this group living in developed countries. The bottom 50% of the world population contributed only 12% of total emissions.[13] (See "Environmental Justice Factsheet")

- Non-OECD countries' CO_2 emissions are expected to grow by 1.0% annually, while OECD countries' emissions are expected to grow by 0.2% annually. Despite this difference, OECD countries will still have per capita emissions 2.2 times higher than non-OECD countries in 2050.[15]

United States

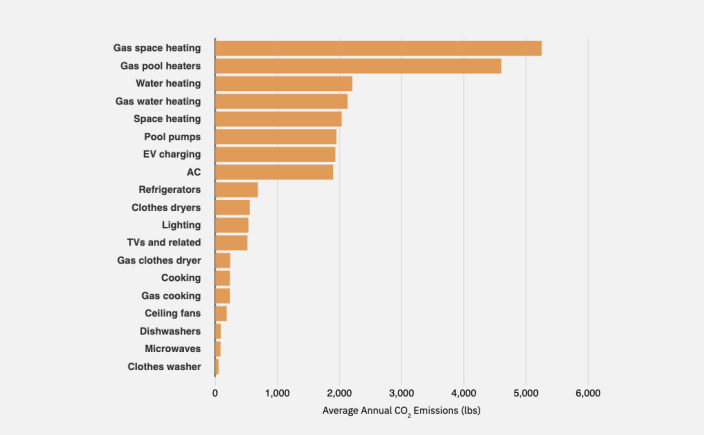
- The U.S. contains 4.2% of the world's total population,[16] but emitted 11.2% of total anthropogenic GHG emissions in 2022.[8] U.S. GHG emissions in 2022 were 3.0% lower than in 1990, with an average annual decline of 0.1%.[5]
- CO_2 emissions, accounting for 79.7% of total U.S. GHG emissions in 2022, were 1.5% lower than in 1990 and 17.5% lower than in 2005.[5]
- Fossil fuel combustion is the largest source of U.S. GHGs, 74.1% of total emissions. Since 1990, CO_2 emissions from fossil fuel combustion have declined by 0.035% yearly.[5]
- Both GHG emissions and fossil fuel emissions declined since 2005, by 15% and 18% respectively, while GDP grew 36%.[5]

U.S. GHG Emissions by Sector (Mt CO_2e)[5]



- Transportation has been the largest U.S. GHG emissions sector since 2017, responsible for 28.4% of total emissions in 2022. Transportation emissions in 2022 were 8% lower than in 2005, but 18.4% higher than in 1990. The growth since 1990 was driven by increased travel demand from population and economic growth, urban sprawl, and low fuel prices.[5]
- Passenger cars and light-duty trucks accounted for 370 and 660 Mt CO_2e, respectively, together making up 57% of U.S. transportation emissions and 16% of total U.S. emissions.[5]
- The electric power industry produced 25% of U.S. GHG emissions in 2022. This sector is the only one showing significant declines, with emissions down 16% since 1990 and 36% since 2005.[5]
- A 2018 study found that the U.S. oil and gas industry emitted 2.3% of its gross NG production annually, equivalent to 13 Mt of CH_4—nearly 60% higher than U.S. EPA estimates.[17]

Average Annual CO_2 Emissions by Activity, 2020 (lbs)[18,19]



- Land use and forestry sequesters CO_2 in growing plants and trees, removing 14.5% of U.S. GHGs emitted in 2022.[5]

Solutions

- Stabilizing global temperatures and limiting the effects of climate change require more than just slowing the growth rate of emissions; it requires absolute emissions reduction to net-zero or net-negative levels.[20] Global CO_2 emissions need to decline 48% from 2019 levels by 2030 and reach net-zero by around 2050 to avoid temperature rise beyond 1.5° C.[21]
- Reducing GHG emissions can be achieved by shifting away from fossil fuels, improving energy efficiency, changing agricultural practices, sustainable forest management and conservation, restoring and conserving critical ecosystems.[22]
- International cooperation is having positive and measurable results in mitigating climate change. A good example is the multilateral global cooperative agreements among nations, such as the 1992 United Nations Framework Convention on Climate Change (UNFCCC), and its related legal instruments, the 1997 Kyoto Protocol and the 2015 Paris Agreement.[9] (See "Climate Change: Policy and Mitigation Factsheet")
- Nationally Determined Contributions, or NDCs, are countries' self-defined national climate pledges under the Paris Agreement, stating their commitments to help meet the global goal of a 1.5°C warming.[23] As of September 2023, the 168 latest NDCs cover 95% of 2019 global emissions, and are projected to limit warming to a range of 2.1-2.8°C.[24]
- As of October 2023, half of the world's largest companies have set net-zero emissions targets, covering $27 trillion or 66% of aggregate annual revenue.[25]

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Sources for this factsheet are here, help with units and abbreviations is here.