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 back 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. Human activities that produce GHGs (anthropogenic) amplify the greenhouse effect. Anthropogenic GHG emissions are modifying the Earth’s energy balance between incoming solar radiation and the heat released back into space, resulting in climate change.1

The Main Greenhouse Gases

Greenhouse Gases

- There are ten primary GHGs; of these, water vapor (H2O), carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) are naturally occurring. Perfluorocarbons (CF3, C2F4), hydrofluorocarbons (CHF3, CFCHF2, CH2CHF2), and sulfur hexafluoride (SF6) are only present in the atmosphere due to industrial processes.2
- Water vapor is the most abundant and dominant GHG in the atmosphere. Its concentration depends on temperature and other meteorological conditions, and not directly upon human activities.3
- CO2 is the primary anthropogenic greenhouse gas, accounting for 78% of the human contribution to the greenhouse effect in 2010.2
- Global Warming Potentials (GWP’s) indicate the relative effectiveness of GHGs in trapping the Earth’s heat over a certain time horizon. CO2 is typically used as the reference gas and has a GWP of one.2 For example, the 100-year GWP of SF6 is 22,800, indicating that its radiative effect on a mass basis is 22,800 times as powerful as CO2 over the same time horizon.4
- GHG emissions are typically discussed in terms of mass of carbon equivalents or carbon dioxide equivalents (CO2e), which are calculated by multiplying the mass of emissions by the GWP of the gas.4

Atmospheric Greenhouse Gas Emissions

- During the last 250 years, atmospheric concentrations of CO2, CH4, N2O, increased by 40%, 150%, and 20%, respectively, to levels which are unprecedented within the past 800,000 years.1
- Pre-Industrial Revolution, the concentration of CO2 remained around 280 parts per million (ppm) by volume.5 In March 2019, the global monthly average concentration increased to 411.04 ppm, which is about 2.5 ppm higher than in 2018.6

Sources of Greenhouse Gas Emissions

- Anthropogenic CO2 is emitted primarily from fossil fuel combustion. Iron and steel production, petrochemical production, and cement production are other significant sources of CO2 emissions.4
- The U.S. oil and gas industry emits 2.3% of its gross gas production, equivalent to 13 million metric tons of methane each year—nearly 60 percent higher than EPA reports.7
- CH4 and N2O are emitted from both natural and anthropogenic sources. Domestic livestock, landfills, and natural gas systems are the primary anthropogenic sources of CH4. Agricultural soil management (fertilizer) contributes 74% of anthropogenic N2O. Other significant sources include mobile and stationary combustion, and livestock.8
- Hydrofluorocarbons (HFCs) are the fastest growing category of GHG and are used in refrigeration, cooling, and as solvents in place of ozone-depleting chlorofluorocarbons (CFCs).9

Emissions and Trends

Global

- In 2010, total global anthropogenic GHG emissions were 49 Gt CO2e. Since 1970, annual anthropogenic GHG emissions increased by 81%.7
- GHG emissions increased by 1.0 Gt CO2e per year from 2000 to 2010. For comparison, emissions averaged an increase of 0.4 Gt CO2e per year from 1970-2000.3
- Emissions from fossil fuel combustion account for a majority (65%) of global anthropogenic GHG emissions.2 In 2016, global emissions of CO2 from energy use totaled 35.7 Gt CO2.9
- From 2000 to 2016, global CO2 emissions from energy use increased 46%.9
- Since 2005, China has been the world’s largest contributor of CO2 emissions, surpassing the U.S.9

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Use of a 100W light bulb for 10 hours:
1,05 lbs CO$_2$\textsuperscript{e}\textsuperscript{13}

1 mile driven in a car (29.1 mpg):
0.67 lbs CO$_2$\textsuperscript{4}

1 mile driven in a light-duty vehicle (21.2 mpg):
0.93 lbs CO$_2$\textsuperscript{4}

Future Scenarios and Targets

- Stabilizing atmospheric CO$_2$ concentration requires more than just slowing the growth rate of emissions; it requires absolute emissions reduction.\textsuperscript{15}
- Based on current climate regulations, global energy-related CO$_2$ emissions are anticipated to increase by 26\% from 2015 to 2050.\textsuperscript{26}
- Non-OECD countries’ CO$_2$ emissions are expected to increase by .9\% annually, significantly faster than OECD countries at 0.2\% annually. Despite these increases, OECD countries will have per capita emissions 2.5 times higher than non-OECD countries in 2050.\textsuperscript{46}
- Under the Kyoto Protocol, developed countries agreed to reduce their GHG emissions on average by 5\% below 1990 levels by 2012. Had the U.S. ratified the Kyoto Protocol, its reduction requirement would have been to reduce its emissions by 7\%.\textsuperscript{47} When the first commitment period ended in 2012, the Protocol was amended for a second commitment period; the new overall reduction goal would be 18\% below 1990 levels by 2020.\textsuperscript{8}
- In 2015, UNFCCC parties came to an agreement whose aim is to limit global temperature rise to below 1.5\° C below pre-industrial levels, in order to avoid the worst effects of climate change.\textsuperscript{9}
- Global CO$_2$ emissions would need to decline 45\% from 2010 levels to avoid temperature rise beyond 1.5\° C.\textsuperscript{90}

1 Teragram (Tg) = 1000 Giga grams (Gg) = 1 million metric tons = 0.001 Giga tons (Gt) = 2.2 billion pounds (lbs)


\textsuperscript{8} Climate and Clean Air Coalition (2016) National HFC Inventories


\textsuperscript{12} U.S. EPA (2016) Learn About the Greenhouse Gas Reporting Program (GHGRP).


\textsuperscript{15} National Research Council (2011) Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia.


\textsuperscript{17} UN Environment Programme (UNEP) and UN Framework Convention on Climate Change (UNFCCC) (2003) Climate Change Information Kit.

\textsuperscript{18} UNFCCC (2013) “Kyoto Protocol.”

\textsuperscript{19} UNFCCC (2018) “Paris Agreement.”

\textsuperscript{20} UN IPCC (2018) “Special Report: Global Warming of 1.5 C.”