GHG 101: GWP & greenhouse effect
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Greenhouse Gas Mitigation on Working Lands

How Greenhouse Gases Affect Climate

In agriculture, we focus on just three greenhouse gases (CO_2, CH_4 & N_2O) which come from: respiration by living organisms (e.g. bacteria, livestock, humans); gaseous losses of nitrogen from agricultural fields; and combustion from forest fires, firewood, or fossil fuels.

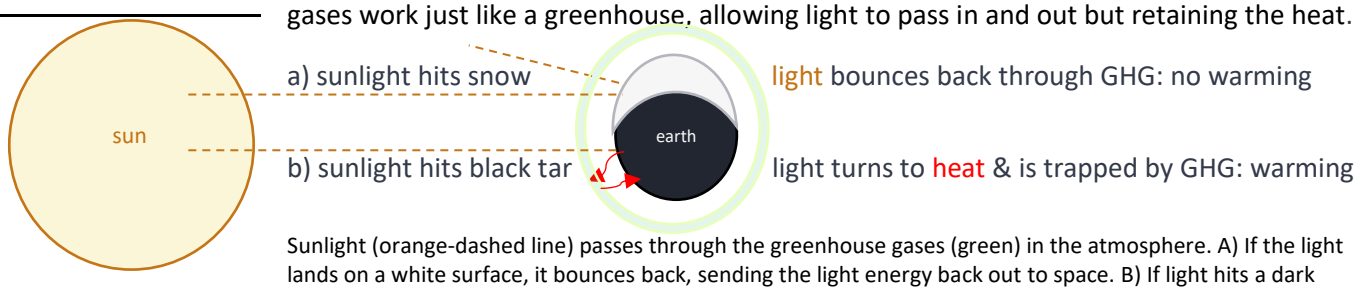
To reduce climate change, we need to understand how greenhouse gases (GHG) change the climate, the difference between the three main gases from agriculture, and how to account for these differences so society can track progress in reducing the impact to future generations. This fact sheet answers these 3 questions:

1) **What causes climate change?**
   GHG in the atmosphere warm the climate through the 'greenhouse effect'.
2) **Do all GHG have the same impact?**
   No. Some last a decade in the atmosphere while others last centuries; some are much more able to hold heat in the atmosphere than others.
3) **How do we do account for GHG with different lifespans and warming ability?**
   Scientists have created a factor called a Global Warming Potential (GWP) to convert tons of a GHG into tons of carbon dioxide equivalent (CO_2e or CO_2eq).

The Greenhouse Effect

The Earth's climate is always changing, but the term "climate change" means a significant change over decades from one climatic condition to another. During recent decades human-caused climate change has occurred much, much faster than previous natural climate changes. Since the beginning of the Industrial Revolution, the large increase in combustion of fossil fuels for energy has greatly increased the concentration of carbon dioxide (CO_2) in the atmosphere. In 2019 total US emission was 6,558 million metric tons of CO_2 equivalents, or CO_2e (USEPA, 2021).

Carbon dioxide is the main greenhouse gas (GHG) but there are many other GHGs. A GHG allows light to pass through it, but it doesn't let heat pass through it. A GHG warms the earth because the gas allows sunlight to pass through our atmosphere, but if that light is turned into heat (it hits a dark surface like a tarred road), the radiated heat bouncing back from the earth is trapped by the GHGs. If the light hits a white surface (such as snow, see **Albedo**), it bounces back out through the GHG and into space. Greenhouse gases work just like a greenhouse, allowing light to pass in and out but retaining the heat.



Sunlight (orange-dashed line) passes through the greenhouse gases (green) in the atmosphere. A) If the light lands on a white surface, it bounces back, sending the light energy back out to space. B) If light hits a dark surface, it turns into heat (red) which cannot pass thru the GHG: the heat is trapped on earth. The difference between incoming and outgoing radiation is known as a planet's radiative forcing (RF). When forcings result in incoming energy being greater than outgoing energy, the planet will warm (positive RF). More GHG means more warming (see also feedback and albedo).

Different GHG have different potencies.

The ***GWP**, or **Global Warming Potential**,* is a factor that helps differently potent gases be compared by conversion to one common unit: ***carbon dioxide equivalents (CO_2e)***.

Greenhouse gases include

water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons, ozone, perfluorocarbons, and hydrofluorocarbons. These different GHG have different warming ability and different lifespans in the atmosphere. Scientists have created a factor called a Global Warming Potential (GWP) to convert tons of a GHG into tons of carbon dioxide equivalent (CO_2e).

Global Warming Potential (GWP)

The **Global Warming Potential (GWP)** is a measure of the total energy that a gas absorbs over a given period of time (usually 100 years) relative to the emissions of 1 ton of carbon dioxide. Two factors contribute to the GWP: (1) how long it stays in the atmosphere (lifespan or residence time); and (2) the capacity of a GHG to trap heat (radiative forcing). For example, sulfur hexafluoride (SF_6, a synthetic chemical used in industrial applications) is considered one of the most potent GHG, with a lifespan in the atmosphere of 800-3200 years. Fortunately, industry uses very little of this GHG and researchers are looking for alternatives. In contrast, methane (CH_4) is a much more common molecule resulting from biological activities (e.g. livestock, rice paddies, ponds) or from natural gas mining, processing, and transportation. However, CH_4 only lives 9-12 years in the atmosphere. Both CH_4 and SF_6 also have very high capacities to absorb heat.

Scientists have worked together to calculate these GWP values based on the most recent data analyzed by the **Intergovernmental Panel on Climate Change (IPCC)** in **Assessment Reports (AR, Table 1).** The most commonly used GWP values are from the 4th Assessment Report (AR4) published in 2007, the most recent values from AR5, published in 2013. While there are other metrics (**GTP** and **GWP***), GWP is the standard metric to compare GHGs for accounting and mitigation. GWP values can also include **feedback** (+/- fb) and can be calculated as an average over different time periods, such as 20 or 100 years. The unit of GWP is a "**carbon dioxide equivalent" or CO_2e or CO_2eq**, because the other gases are compared to CO_2. Therefore, the GWP of CO_2 is 1. From the AR4 methodology, CH_4 over 100 years has a GWP value of 25 (highlighted in yellow); Using this factor, CH_4 is 25 times more potent than CO_2. To convert from a ton of CH_4 to tons CO_2e, simply multiply by 25. To note: New York State uses AR5 GWP 20yr-fb*.

Table 1: Global Warming Potentials relative to Carbon Dioxide (from IPCC AR 2007-2013).

GHG^	Lifespan (years)	AR4 (2007) 100 year	AR4 (2007) 20 year	AR5 (2013) 100 year	AR5 (2013) 20 year
CH_4	9-12	25	72	34	86*
N_2O	121	298	289	298	268*
SF_6	800-3200	22,800	16,300	23,500	17,500

From: https://archive.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf
^ CH_4, N_2O & CO_2 are the GHG relevant to working lands; SF_6 is an industrial GHG for comparison.
* Note, NYS is using AR5 "GWP20-year minus feedback" (where N_2O=264 and CH_4=84).

To Learn More

, please visit: http://blogs.cornell.edu/workinglands

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