Greenhouse Gases: The Invisible Threat

ENERGY INNOVATION REPORT

ENERGY IMPACT CENTER

What is a greenhouse gas?

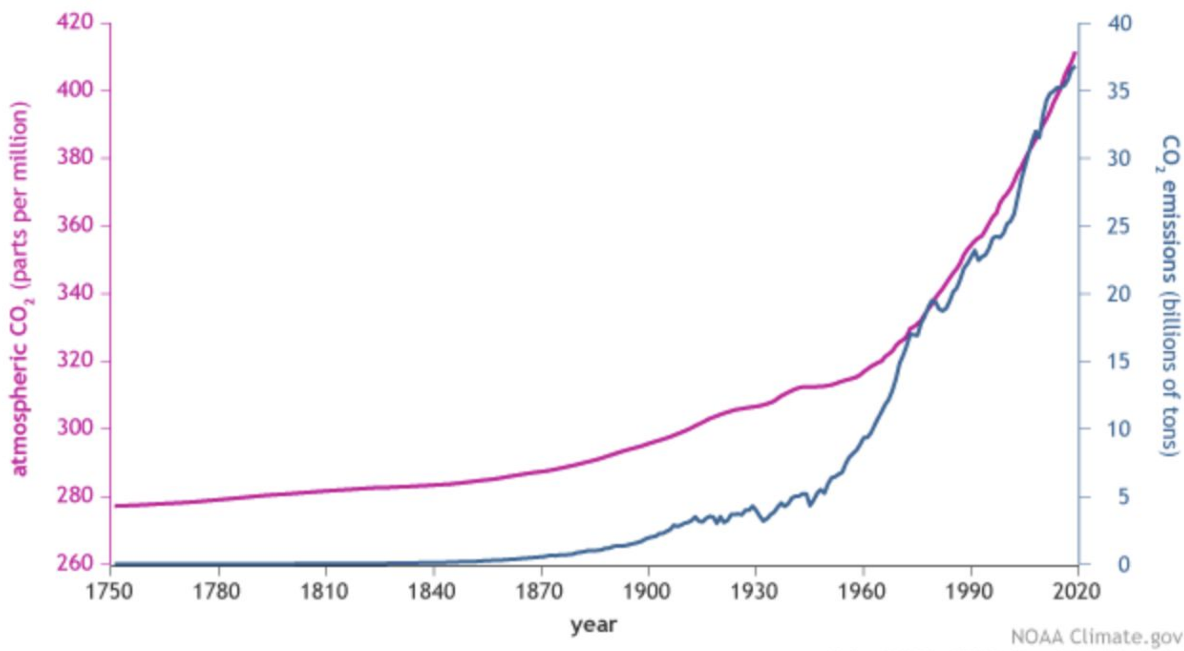
Gases that trap heat in Earth's atmosphere are what's called greenhouse gases (GHGs). They've existed on the planet since its formation.[1] However, any time the words "greenhouse gas" are brought up, they cause an ominous stir, and for good reason.

For most of the past 800,000 years, the concentration of greenhouse gases in the atmosphere have been between 200 and 280 parts per million (molecules of the gases per million molecules of air). In the last century, the concentration of these greenhouse gases has almost doubled to 400 parts per million.[2]

Since the Industrial Revolution began in 1820, human activities have spurred rapid growth in emissions – from the burning of fossil fuels to deforestation. Each year, greenhouse gas emissions have risen to record levels, demonstrated by historical carbon dioxide levels (Figure 1).

Understanding the true implications of greenhouse gases is critical to finding a long-term sustainable solution.

Figure 1. Level of CO2 in the Atmosphere and Rate of Annual Emissions (1750-2019)



Source: NOAA Climate.gov, Data: NOAA, ETHZ, Our World in Data

What makes greenhouse gases so bad?

Greenhouse gases themselves are not inherently harmful, in fact they enable the Earth to be inhabitable by warming it to a global average of 15°C.[3] Without this greenhouse gas layer in the atmosphere, the heat would radiate back into space and the Earth would be too cold for liquid water to form.[2] This greenhouse effect was identified by scientists as far back as 1859.[4]

Due to a drastic imbalance in the Earth's ability to absorb the rapid increase in GHG emissions since the Industrial Revolution, the impact of the greenhouse effect has changed significantly. As these anthropogenic gases accumulate in the atmosphere, the warming effects increase unpredictably.

Types of Greenhouse Gases

The most prominent greenhouse gas is carbon dioxide (CO_2). This chemical is at the top of mind for many as it's emitted through industries like transportation and electricity that directly impact our lives.

One may also think of methane (CH_4). This gas is emitted during the production and transport of coal, natural gas, and oil. It can be found through the decay of organic waste in landfills. And it is mostly associated with the emissions of livestock and other agricultural practices.

Each year a single cow releases approximately 220 pounds of methane.[5] This methane gas emitted is shorter-lived than carbon dioxide, but 28 times more potent in warming the atmosphere. Studies have shown that over a 20-year period, a kilogram of pure methane (stronger than what is coming from cows) warms the planet as much as 80 times more than a kilogram of carbon dioxide.[6]

Even though carbon dioxide and methane are two of the most known greenhouse gases and represent large percentages of overall emissions, they aren't the worst. That title goes to sulfur hexafluoride (SF_6).

Sulfur hexafluoride is lesser known in comparison to carbon dioxide and methane. It is a cheap, non-flammable, odorless, completely man-made, synthetic gas. It is used in the energy industry in grid insulated switchgear helping to prevent short circuits, electrical accidents, and fires.[7]

Although its purpose is for safety, it poses a risk to increasingly harm our atmosphere. Sulfur hexafluoride has a global warming potential of 22,800 times that of CO_2 over a 100 year period and it can stay in the atmosphere for 3,200 years. In comparison, carbon dioxide can stay for hundreds of years and methane for 12 years (Table 1).[8]

Table 1. Global Warming Potential (GWP) and Atmospheric Lifetime of Key Greenhouse Gases

Greenhouse Gas	100-Year GWP	Lifetime (Years)
Carbon Dioxide (CO_2)	1	hundreds
Methane (CH_4)	25	12
Sulfur hexafluoride (SF_6)	22,800	3,200

Source: Selected Gases from Table 2.14 in the IPCC AR4 WG-I Report.

The Most Common Greenhouse Gas

The most impactful to our atmosphere is a greenhouse gas often overlooked — H_2O. Water vapor traps more heat in Earth's atmosphere than any other previously mentioned greenhouse gas.[9] Although that may come as a surprise, it makes sense when you consider that 71% of Earth's surface is covered in water.[10]

As mentioned before, greenhouse gases, including water vapor, themselves aren't inherently problematic. It is their interaction with infrared radiation which causes rapid warming.

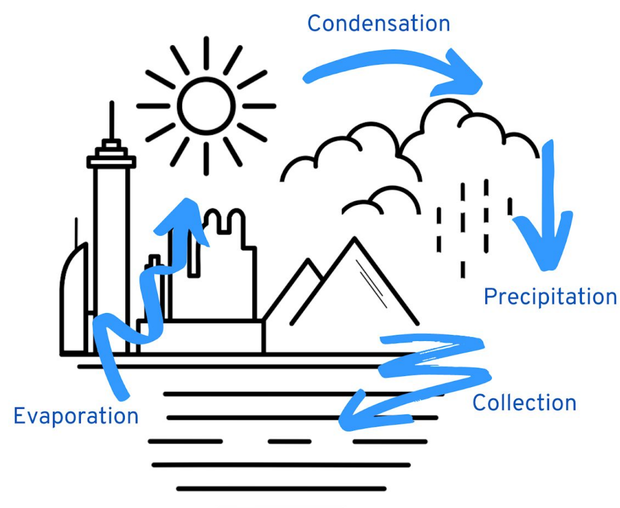
Gases like nitrogen, oxygen, and argon, which are non-greenhouse gases, but found in our atmosphere, consist of only one to two atoms. They each have a strong covalent bond and no electrical charge. Ultimately, they are invisible to infrared radiation.[11] The greenhouse gases described above, carbon dioxide, methane, sulfur hexafluoride, and water vapor, have multiple bonds of atoms of different elements giving them a slight electric charge and the ability to bend and flex.[12]

When infrared wavelengths pass close to the molecule it gets absorbed by these electrical fields. This extra energy then resonates through the bonds causing them to stretch, bend, and vibrate. These wavelengths and protons are eventually sent back out as infrared radiation into space, towards the ground, or across the atmosphere where they can interact with other greenhouse gas molecules and create more water vapor.[13]

The more water vapor there is in the air, the more humid the air becomes. Naturally, the water cycle can help resolve this. Water vapor eventually reaches a saturation point, condenses into clouds, and falls to the ground as rain, only to evaporate into the atmosphere again (Figure 2).[14]

Although the water cycle has kept the climate relatively stable over the past couple thousand years, it is showing signs of faltering. The amount of water vapor the air can hold can change.

Figure 2: The Water Cycle



The higher the amount of energy in the atmosphere, the more water that it can hold. For this to happen, something must raise the energy level of the atmosphere to make more room for water vapor in the air.

The Missing Link: Humans

Historically, atmospheric energy levels have risen due to natural occurrences like volcanic eruptions or asteroid impacts. Today, the extreme excess of greenhouse gases released through human activity is taking us off course. Once these GHGs are released into the air, they absorb infrared radiation and trap heat, making room for more water vapor. The resulting impact on the global water cycle lays the foundations for extreme weather, natural disasters, and loss of life.

Today, most GHG emissions come from electricity generation, industry, and agriculture-related activity.[15] Of these emissions, more than 70% are carbon dioxide, followed by methane and nitrous oxide.[16] Although water vapor remains a strong greenhouse gas, human contributions to atmospheric H_2O is negligible when compared to the other GHGs.

Conclusion

None of the greenhouse gases are categorically harmful to the health of the planet. When compounded by the growing rate of human activity and the already accumulated GHGs in the atmosphere, the once benign greenhouse effect quickly becomes malignant. In order to address the current state of the climate, policymakers will have to take a holistic approach to a complex problem.

Global greenhouse gas emissions fell by 6.4% through the COVID-19 pandemic, but this effect is not enough to bring long term emissions reductions.[17] We still need solutions that slow emissions and actually capture much of the gas already in our atmosphere. To properly address global climate change, the international community will have to become emissions negative and reverse the accumulation of GHGs in our atmosphere.

Endnotes

Further information, references, and hyperlinks

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