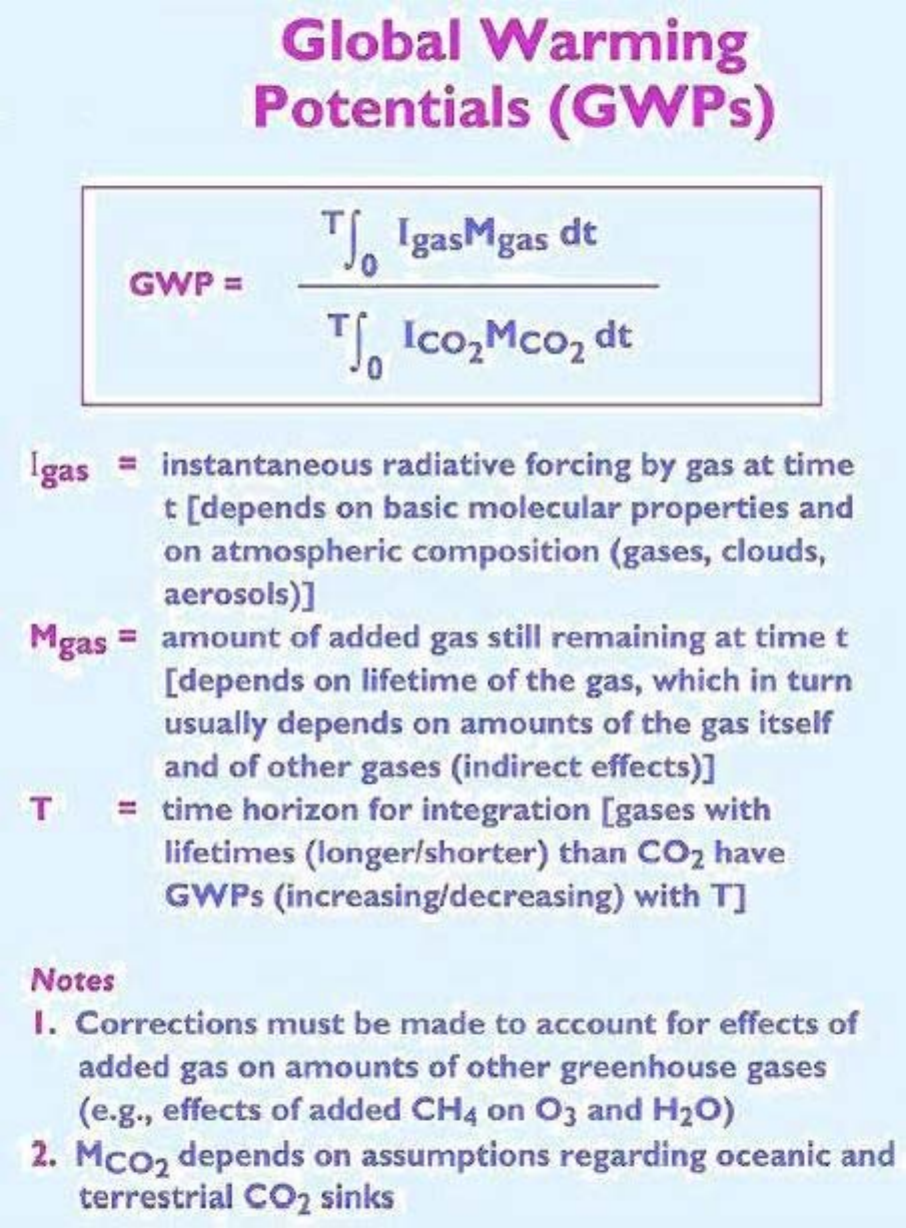
Slide 1



Global Warming Potentials (GWPs)

$$GWP = \frac{\int_0^T I_{gas} M_{gas}\,dt}{\int_0^T I_{CO_2} M_{CO_2}\,dt}$$

I_{gas} = instantaneous radiative forcing by gas at time t [depends on basic molecular properties and on atmospheric composition (gases, clouds, aerosols)]

M_{gas} = amount of added gas still remaining at time t [depends on lifetime of the gas, which in turn usually depends on amounts of the gas itself and of other gases (indirect effects)]

T = time horizon for integration [gases with lifetimes (longer/shorter) than CO_2 have GWPs (increasing/decreasing) with T]

Notes

1. Corrections must be made to account for effects of added gas on amounts of other greenhouse gases (e.g., effects of added CH_4 on O_3 and H_2O)
2. M_{CO_2} depends on assumptions regarding oceanic and terrestrial CO_2 sinks

This slide shows how Global Warming Potential (GWP) is calculated. GWP is a simple and commonly used method to estimate the warming effects of different long-lived greenhouse gases relative to each other. GWPs are expressed in terms of emissions of carbon dioxide, the most common and important human-induced greenhouse gas because of its abundance and ability to absorb energy in the form of infrared radiation which produces heat. GWPs are always calculated with a particular time frame to measure the impact of the greenhouse gas.

Because GWP is always expressed relative to CO_2, CO_2's GWP is exactly 1.

Methane (CH_4) has a GWP of 24 over a 100 year period, meaning that the emission of 1 ton of CH_4 is the same as the emission of 24 tons of CO_2 over a 100 year period.

Let's explore how to calculate GWP in more detail.

GWP for a gas is calculated by taking into account their estimated duration in the atmosphere and their ability to absorb outgoing infrared radiation (a form of energy capable of causing heat). Thus, GWP has two components. More precisely, GWP is the ratio of the amount of radiation a unit emission of the gas absorbs over a given time frame (100 years for example), as compared with how much radiation a unit emission of CO_2 absorbs in the atmosphere over the same time period.

As already noted, CO_2's GWP is 1. For a gas that has the same radiation absorption capability and lifetime as CO_2, the GWP will be 1.

If a substance lasts longer in the atmosphere than CO_2, it will have a component of the GWP larger than 1, and a substance which lasts shorter than CO_2 will have a component of the GWP smaller than 1.

Similarly, a substance which absorbs more infrared radiation than CO_2 will have the second component larger than 1, and a substance which absorbs less infrared radiation than CO_2 will have a second component smaller than 1. The net GWP is the multiple of these two components, integrated (or summed) over the time frame.

As you know CH_4 has a GWP of 24. Although the lifetime of CH_4 in the atmosphere is shorter than that of CO_2 (which alone would cause it to have a smaller GWP than CO_2), CH_4's ability to absorb infrared radiation is much larger than CO_2. In the case of CH_4, the ability to absorb radiation outweighs the shortness of its life in the atmosphere. Therefore, CH_4 has a higher GWP than CO_2.

As we said, GWP is a simple measure. There are many problems with using GWP. One example is that it is difficult to predict the lifetime of a gas that is highly reactive to other gases in the atmosphere because the gas's lifetime is likely to be hard to quantify and have a changing lifetime, over the time period of measurement. Also, because our measurement tools are imprecise, it is difficult to measure the composition of the atmosphere accurately as it changes. Finally, as substances interact and change in the atmosphere, their ability to absorb outgoing radiation can also change. As a result, its ability to absorb outgoing infrared radiation may also change over time.

Slide 2

Global Warming Potentials

GWP values and lifetimes from 2007 IPCC AR4	Lifetime – years	GWP time horizon		
		20 years	100 years	500 years
Methane	12	72	25	7.6
Nitrous Oxide	114	310	298	153
HFC-23 (hydrofluorocarbon)	270	1,200	14,800	12,200
HFC-134a (hydrofluorocarbon)	14	3830	1430	435
Sulfur Hexafluoride	3,200	16,300	22,800	32,600

This table shows GWPs for various major greenhouse gases. Remember that Carbon Dioxide has a GWP of 1, and that all other greenhouse gas GWPs are measured in comparison to Carbon Dioxide.

After Carbon Dioxide, Methane is the next most important GHG, because it has high capacity to absorb infrared radiation and is relatively abundant. Reading from left to right for Methane, the observed lifetime of methane, in today's atmosphere, is on average 12 years. Methane has a GWP of 72 over a 20 year period, meaning that over this time period, the emission of 1 ton of methane will have the same climate impact as the emission of 72 tons of carbon dioxide, or in other words methane is 72 times stronger than carbon dioxide. When looking at a 100 year period of time, however, the emission of 1 ton of methane has the same climate impact as the emission of 25 tons of carbon dioxide.

Why does methane decrease from a GWP of 72 to 25 as we go from a 20 year to 100 year time horizon? It is because Methane has an average lifetime of 12 years, and as the time horizon increases beyond its average lifetime, an increasing amount of methane is destroyed by interacting with other gases.

In contract, notice that Sulfur Hexafluoride has a much longer lifetime of 3200 years on average. Because it has longer lifetime than carbon dioxide, its GWP increases as the time horizon increases from 20, 100 to 500 years. From 20 to 500 years, sulfur hexafluoride's GWP doubles. Over a 500 year period, the emission of 1 ton of sulfur hexafluoride is the same as the emission of 32,600 tons of carbon dioxide. Therefore, even a tiny amount of sulfur hexafluoride emissions can make a large contribution to climate change.