Basics of greenhouse gases and climate change

Facts and theories

We need to distinguish between what we know (facts), and what we think will happen (theories).

In the subject of greenhouse gases and global warming, we have a handful of facts, and many theories.

Our job will be to recognize the facts, and thus what we know with *near certainty*, and separate these from the theories, which we understand, *have more uncertainty*.

The scientific method problem

The "Scientific Method"… *the religion of science… propose a theory, test it, accept, reject, or modify, repeat…*

Scientists can never prove anything, we can only disprove hypotheses.

We adopt this approach in order to

- *avoid the development of dogma (we're supposed to be trying to shoot down the leading idea of the day…* doesn't always work that way…*)*
- *level the playing field… the skill of the arguer is less important than the logic of the argument… there are not supposed to be scientist-lawyers…* this doesn't always work as well…

The scientific method problem

This approach obviously does not mesh well with how most people think or act….

… try running our legal system this way, for example…

We are comfortable with the concept of "reasonable doubt" and the pitfalls that come with that, but not the concept of "reasonably sure", which is at the heart of the Scientific Method.

The scientific method problem

Combine this with the journalist's mandate of fairness *and we've got a public perception problem…" the scientists are unsure, so what can we do… nothing?…"*

Spinning becomes key, as opposed to the facts. This is the way things work normally, although it greatly upsets scientists…

The scientific method problem

… so what is the role of science in the global warming "debate"?

- Science provides facts and information.
- Science does not provide policy, but it provides information helps to form policy options
- Science plus policy plus ethics plus economics plus sociology plus…. *A "studies" as opposed to 'science" approach is a more complete look at the situation and can lead to better answers*

Radiation budget of the earth

Start with the “facts”…

Fact: The Earth gets its energy overwhelmingly from the sun (a little bit is generated by radioactive decay and friction from within the Earth).

Radiation budget of the earth

Fact: all bodies, above 0˚K, emit radiation, and the *wavelength of the radiation depends on the temperature of the object*… the Blackbody Temperature.

Examples:

- The sun emits most energy in the visible part of the spectrum… hence the light we see by.
- The Earth emits radiation in the infrared part of the spectrum… hence infrared night vision by many animals.
- Popular concepts: “white hot” is hotter than “red hot”.
- Ear thermometers for people.

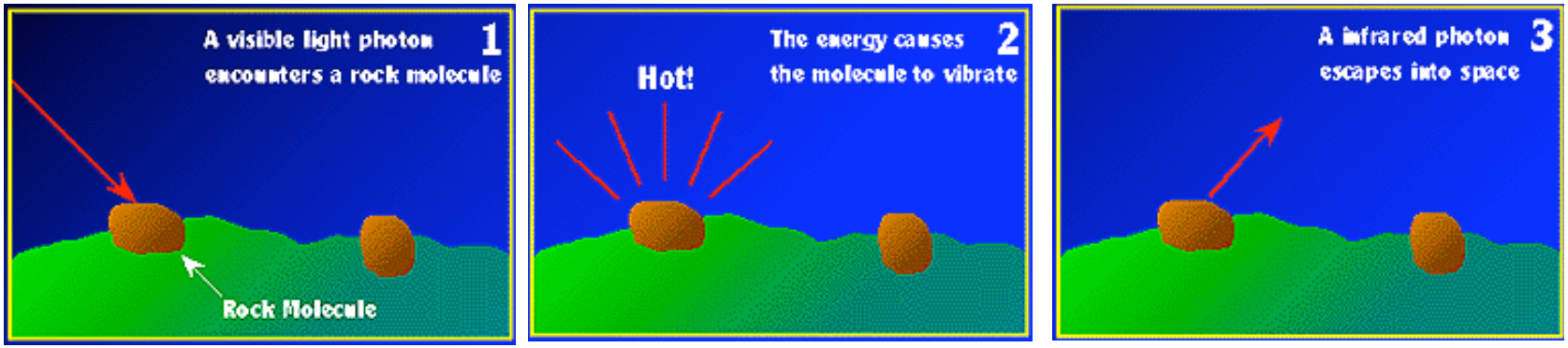
Radiation budget of the earth

We can measure the wavelength of radiation emitted by the Earth's surface…

Fact: The blackbody temperature of the Earth is about –18˚C

Radiation budget of the earth

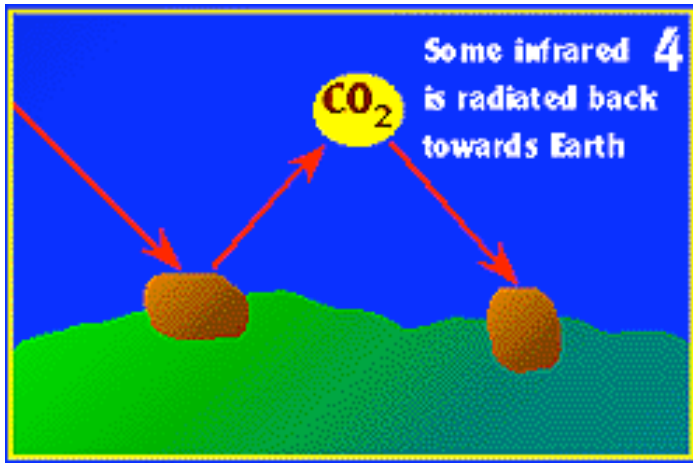
If the Earth was a barren chunk of rock, this would be the average temperature, and, as the Earth gets its energy from the Sun, this would be the temperature set by the Sun's radiation.



Radiation budget of the earth

The Earth is warmer than this. We know this intuitively, as the oceans are not frozen.

Lets add an atmosphere to the Earth and look at the energy balance.



Radiation budget of the earth

This is the greenhouse effect.

Some of the Earth's radiation is absorbed in the atmosphere by gases (greenhouse gases) and when that energy is re-emitted, 1/2 of the energy goes up, to space, but 1/2 goes down, adding energy to the Earth again.

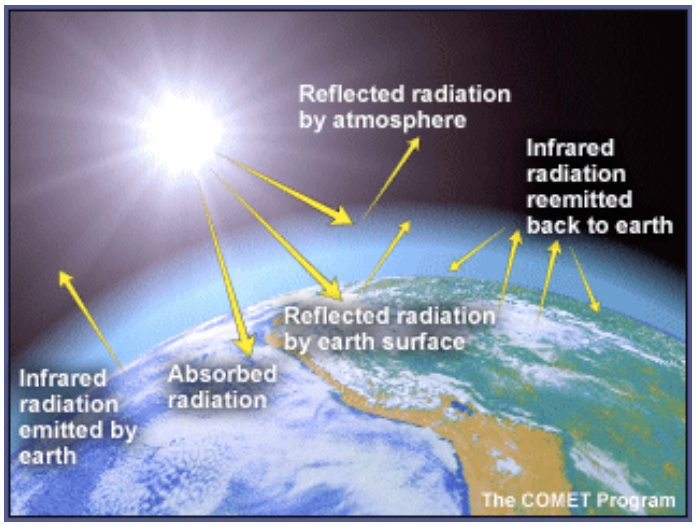
Greenhouse gases

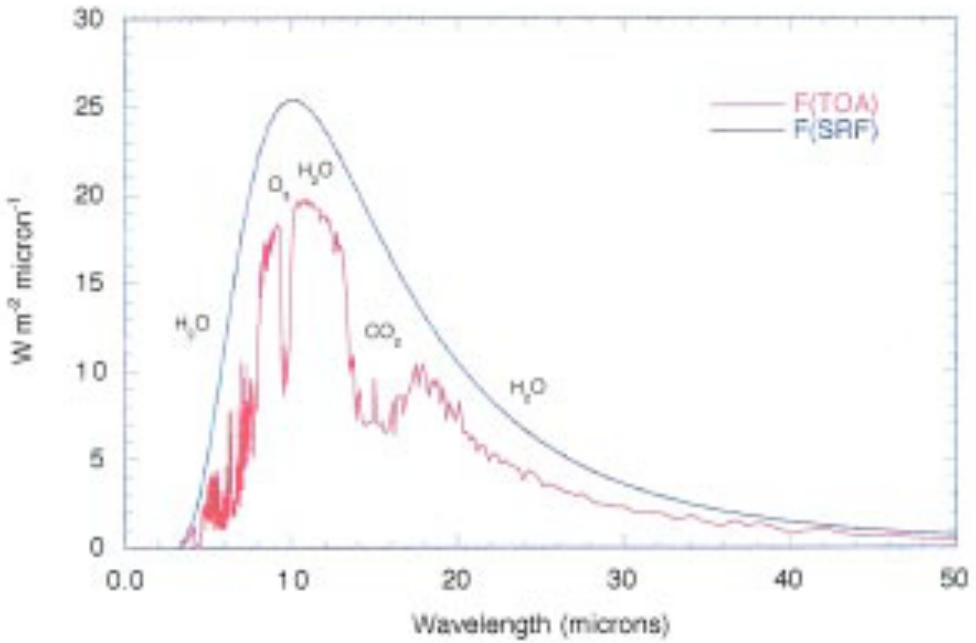
Greenhouse gases are special, in that they must be able to absorb energy of the wavelengths emitted by the Earth.

Which gases do this, and which don't?

What are the greenhouse gases?

In general, any atmospheric gas that is relatively transparent to the Sun's energy but absorbs the Earth's energy





Surface (blue) and top-of-atmosphere (red) upward longwave flux (W m^2/mm) for global cloudy conditions. (Kiehl and Trenberth, BAMS, 1997)

What are the greenhouse gases?

Important factors

- How abundant is it? Bigger is better.
- How effective is it? Or How much competition does it have?
- How long does it stay in the atmosphere (*residence time*)? Longer is better.

- Energy trapping impact: all of the above
- Greenhouse warming potential (GWP): effectiveness and residence time

What are the greenhouse gases?

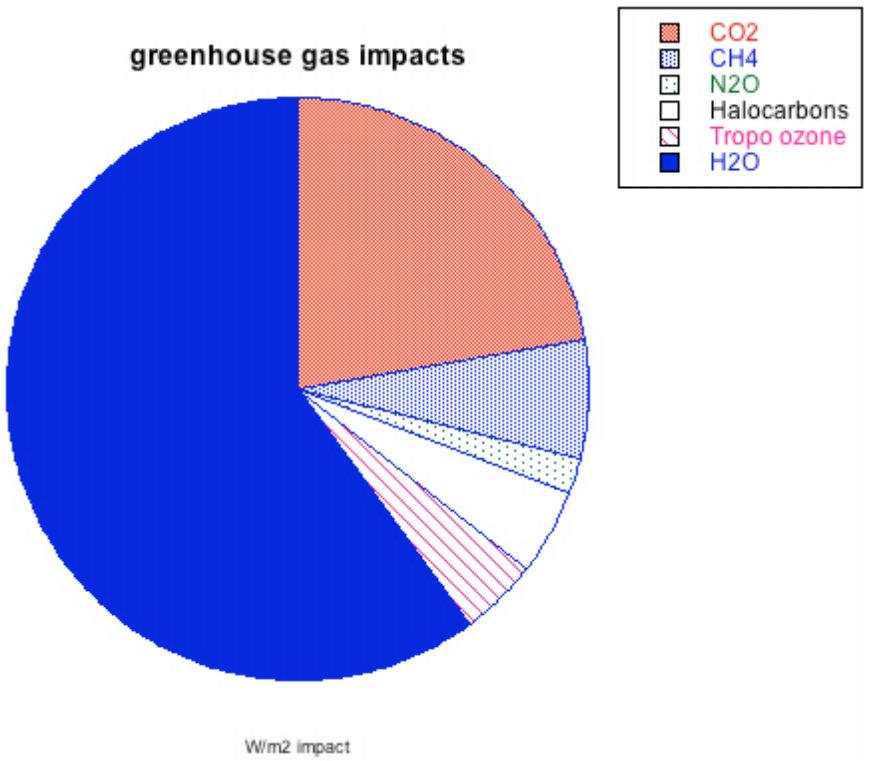
In order of energy trapping impact…

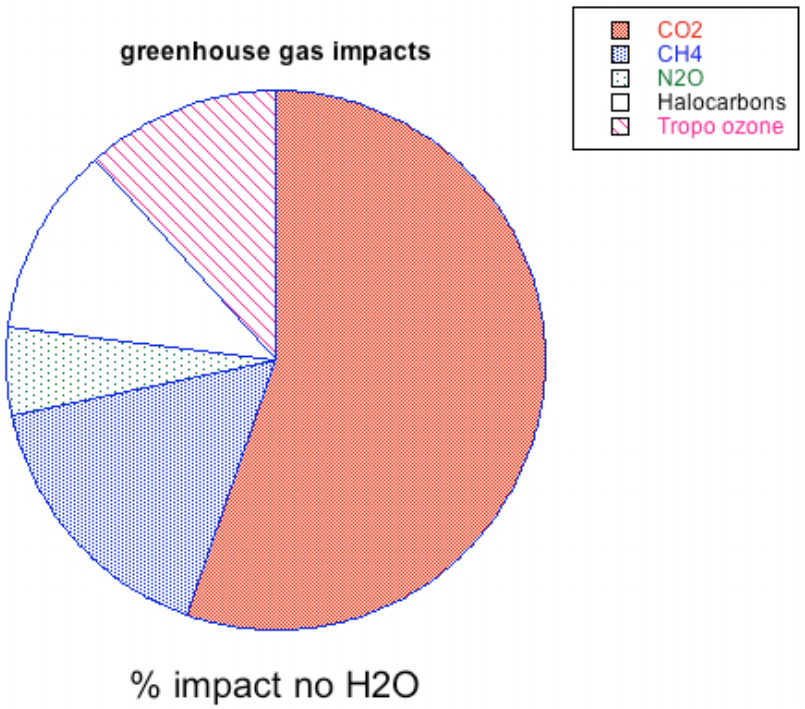
1. Water vapor
2. Carbon dioxide
3. Tropospheric ozone
4. Methane
5. CFCs, HCFCs and HFCs
6. Nitrous Oxide
7. Minor others… sulfur hexafluoride (*transformers*), fluorocarbons (C+F), (*aluminum smelting, semiconductor manufacturing*)

Lies, damn lies, and statistics

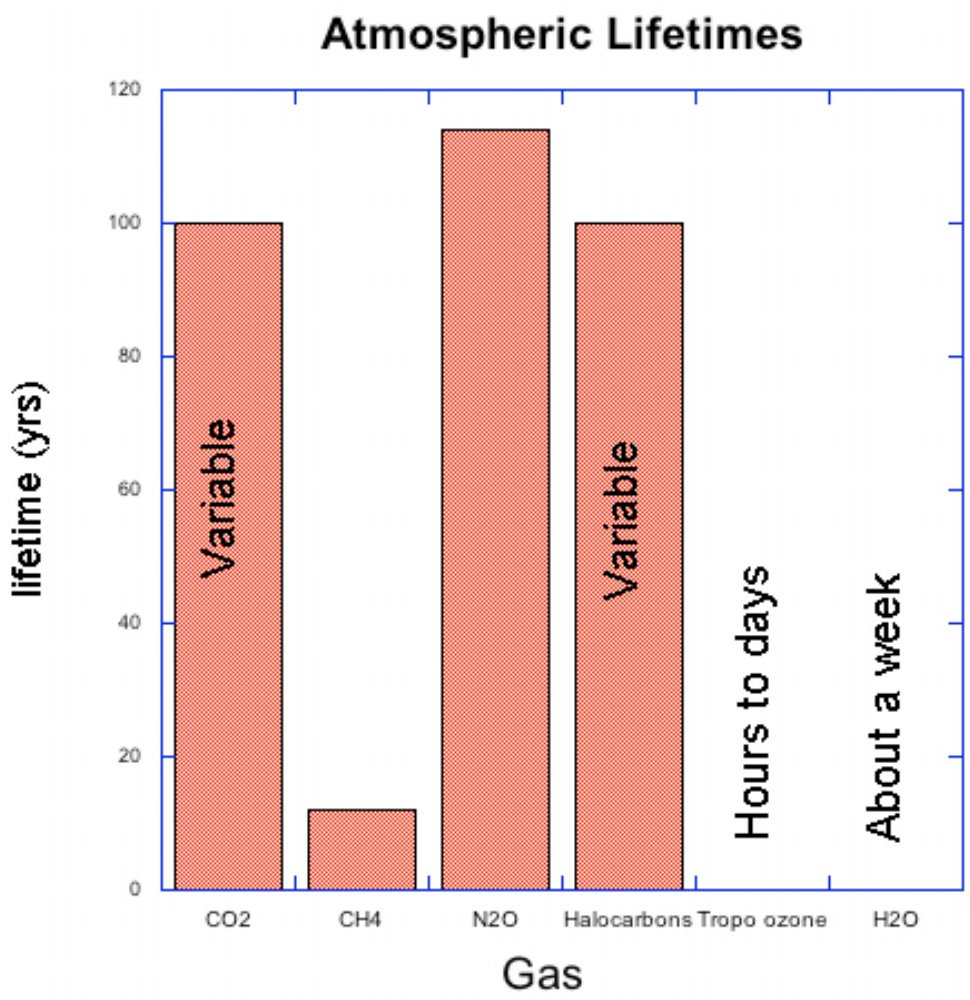
Gas	W/m^2 impact	% impact	% impact (no H_2O)	lifetime (yrs)	Abun-dance	GWP
H_2O	4.50	0.60		0.01	0 to 4%	2.3
CO_2	1.66	0.22	0.55	10-100	380 ppm	1
CH_4	0.50	0.07	0.17	12	1.8 ppm	23
Tropo-spheric ozone	0.35	0.05	0.12	Hours to days	34 ppb	34
Halo-carbons	0.34	0.05	0.11	Years to centuries	1-500 ppt	~10000
N_2O	0.16	0.02	0.05	114	320 ppb	296

With or without vapor?

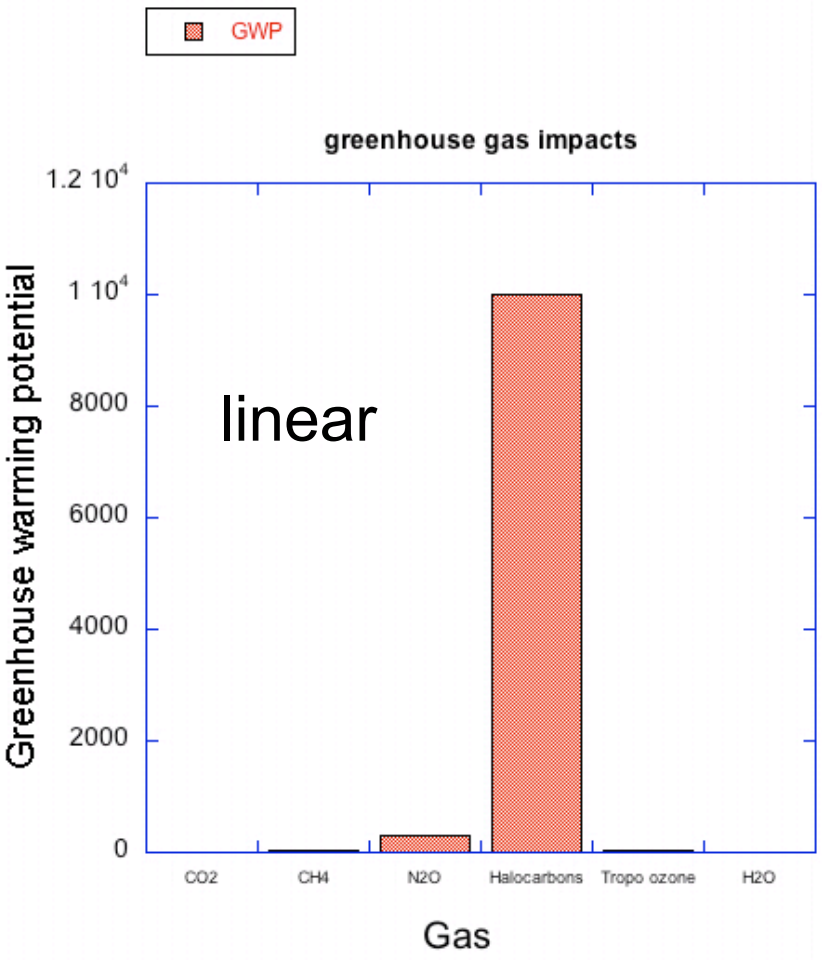


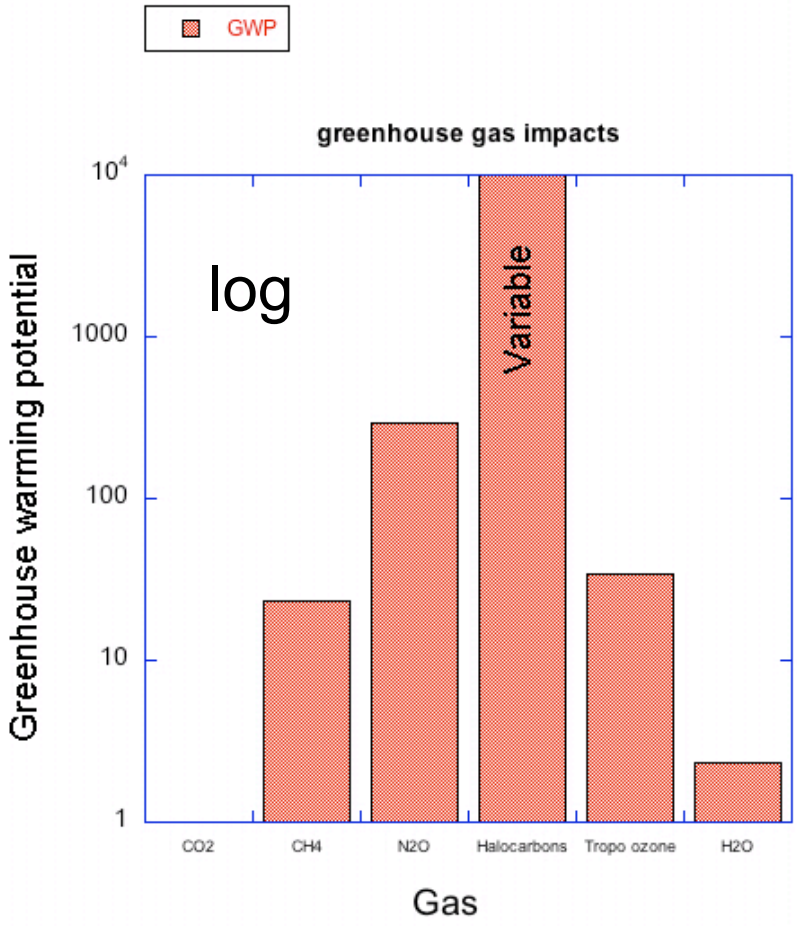


How long will they last?



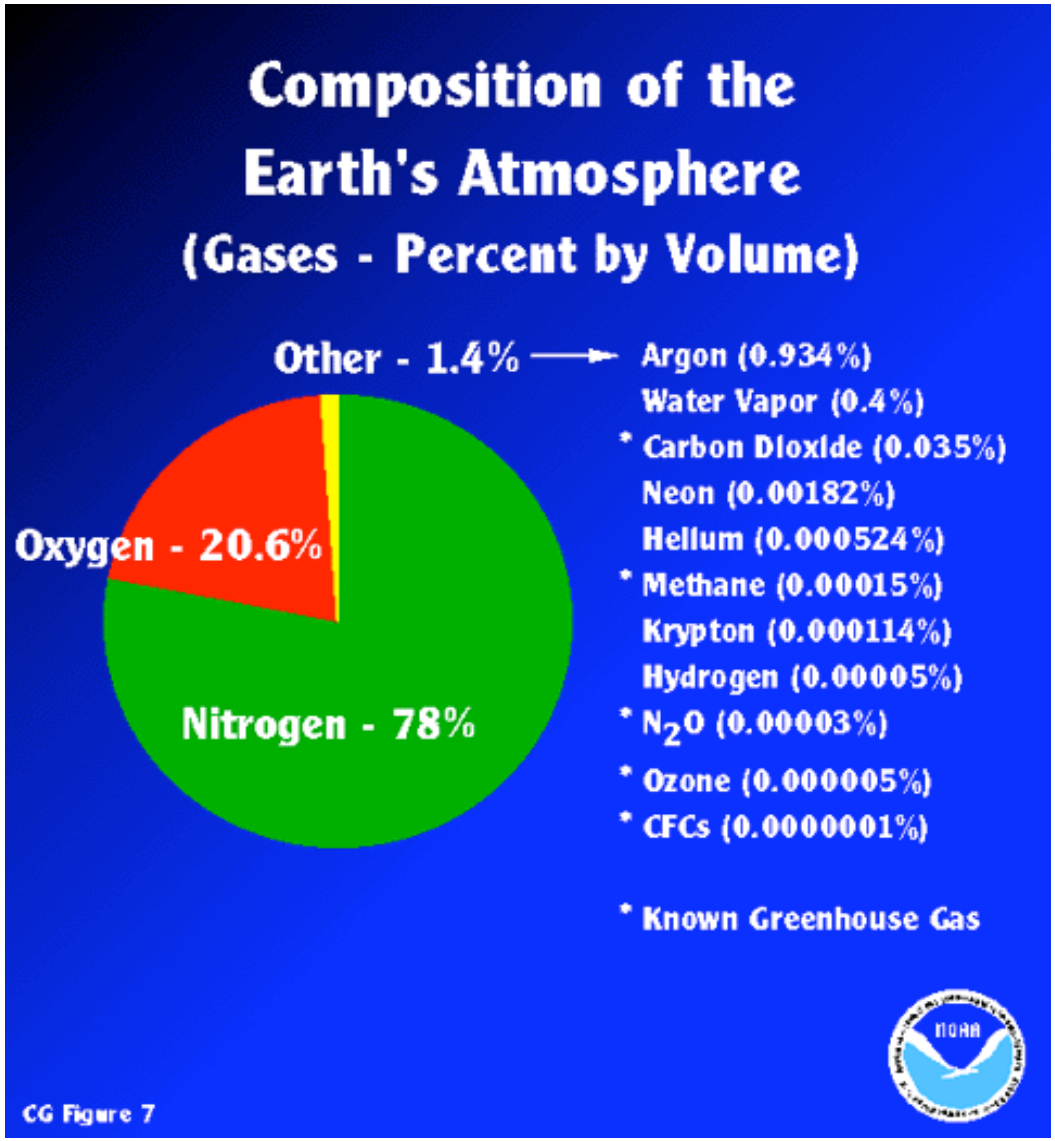
How big is the impact per molecule?





Greenhouse gases

Note that the common gases of the atmosphere, such as nitrogen and oxygen, do not absorb energy emitted by the Earth.



Back to our facts

Back to the temperature of the Earth…

We can also use thermometers to measure the temperature of the Earth *as we perceive it*… that is, the temperature of the air at the Earth's surface.

Back to our facts

Fact: The average atmospheric temperature at the Earth's surface is about 15°C.

Fact: Greenhouse gases are responsible for the 33° increase from blackbody temperature to average air temperature.

Back to our facts

Greenhouse gases probably make the difference between a frozen planet and a wet one. In other words, greenhouse gases make life, as we know it, possible.

Other planets

A little planetary comparison…

Planet	Blackbody temperature (˚C)	Atmospheric temperature (˚C)
Venus	~ +20	~ +450
Earth	-18	+15
Mars	-50	-50

Venus has an atmosphere dominated by greenhouse gases (CO_2), Mars has only a thin atmosphere.

Summary

Its simple…

The greenhouse effect is real, and natural. Without it, would we even have a habitable planet?