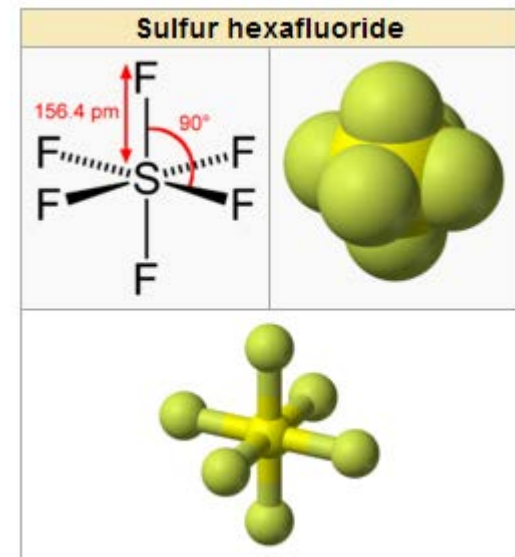
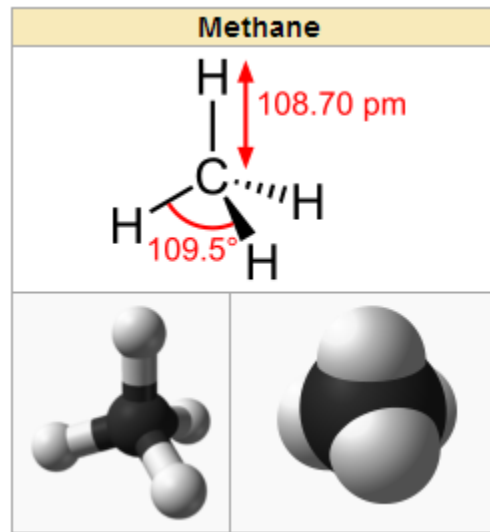
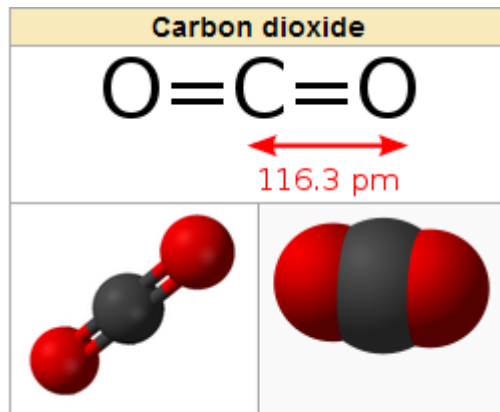


Global Warming Potential (GWP)

Actually more interesting than you might think!

By: Nate Maynard, Leigh Hammel, Michael
Morgan

Which GHG will increase global temperatures the most in the next 20 years?



Answer: at end of presentation

Global Warming Potential (GWP)

An index that measures a GHG's ability to cause global warming based on

- Its ability to absorb infrared photons that would otherwise be leaving the atmosphere
- The life span of the gas in the atmosphere
- The time span of observation

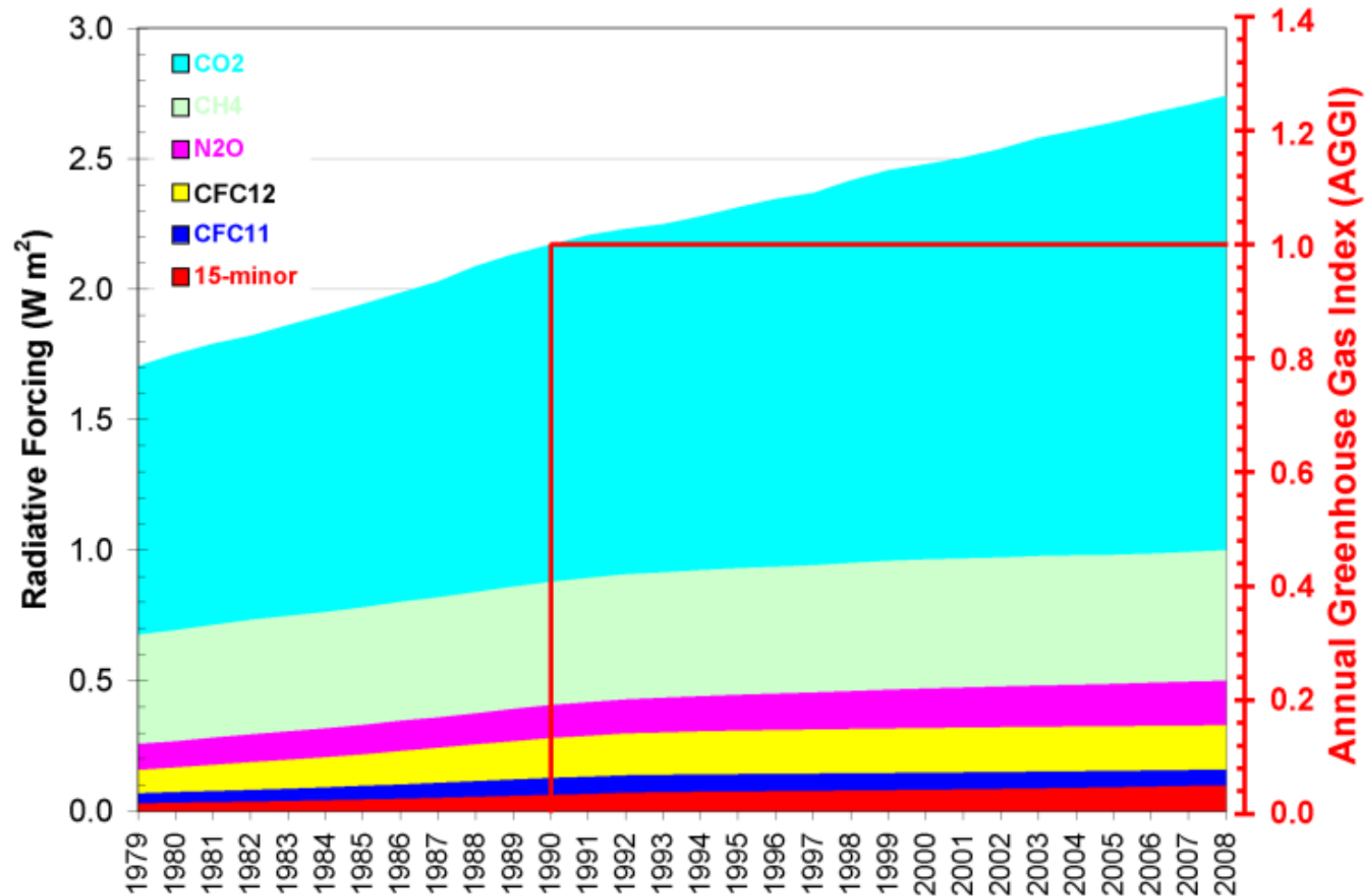
The Factors of GWP - Radiative Forcing Capacity (RF)

The amount of energy per unit area per unit time that is absorbed by the greenhouse gas that would otherwise be lost to space.

In other words - a change in the radiative balance of the earth's surface, which leads to a change in the earth's temperature.

Measured in Watts/m² - or energy per time per unit area

Atmospheric Radiative Forcing of all Long Lived GHGs



Global Warming Potential

GWP – an index comparing other GHGs to CO₂

a_i= Radiative forcing efficiency –
amount of impact a change in
a certain amount of gas will have

c_i(t)=Time dependent decay of the
abundance of a chemical in the
atmosphere – this is where the half

dt= Change in time

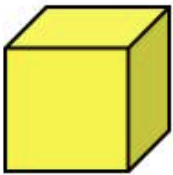
TH= Time horizon of interest

TR = Reference time, usually starting at 0 years

$$GWP_i = \frac{\int_{TR}^{TH} a_i c_i(t) dt}{\int_{TR}^{TH} a_{CO_2} c_{CO_2}(t) dt}$$

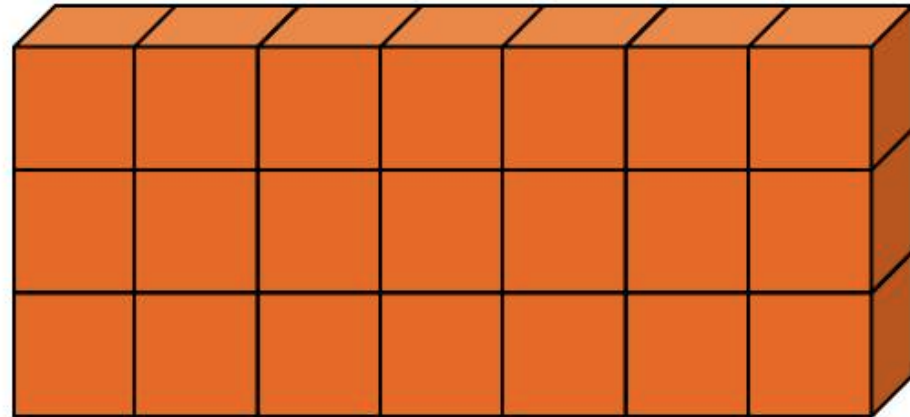
What Does This Mean?!?!?!?!?!?!?!?!?!?!?

1 pound of CH₄

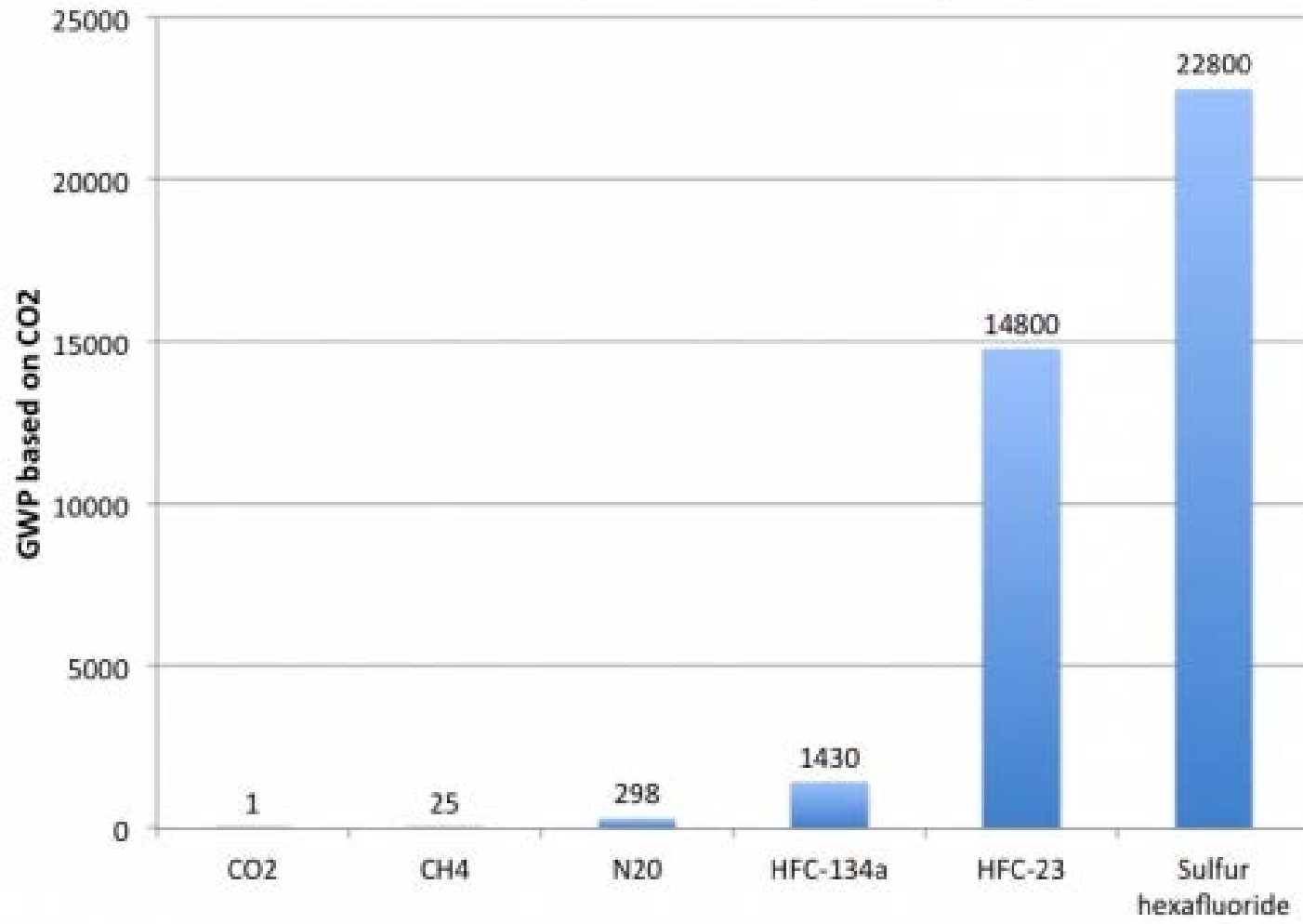


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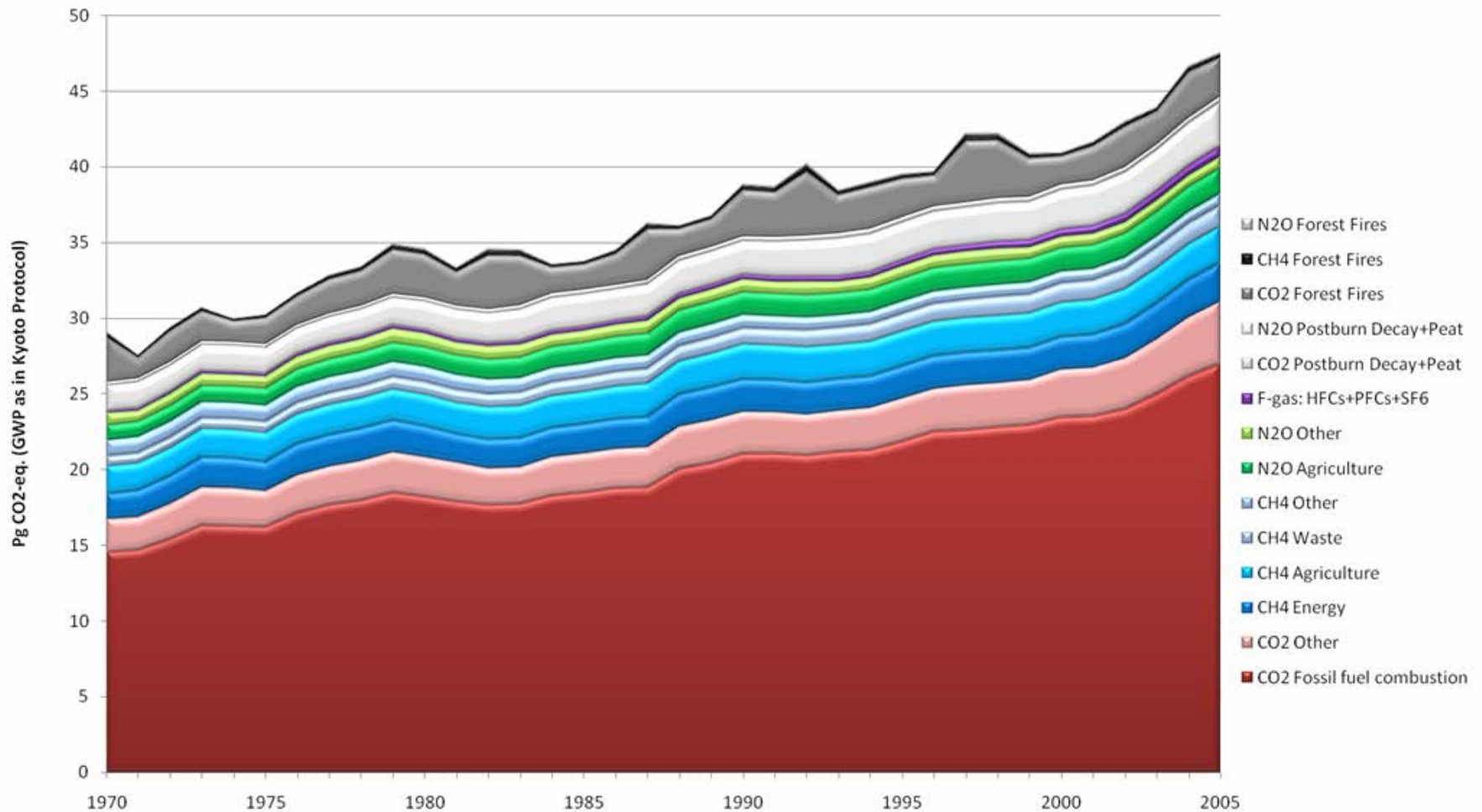
21 pounds of CO₂



Global Warming Potential per 100 years



GWP of Natural GHGs



CO₂ Equivalent - An application of GWP

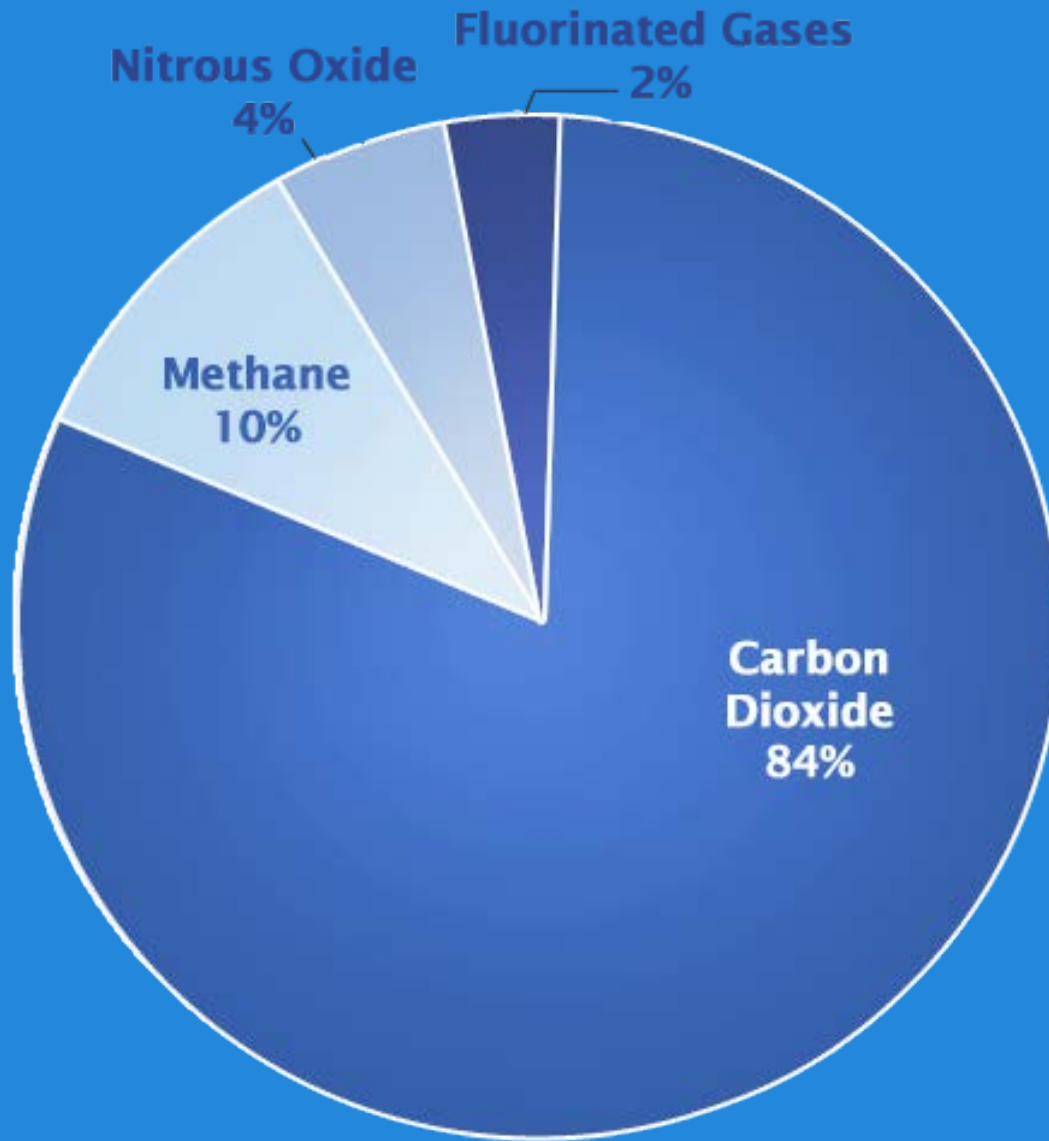
- GHG emissions are often measured in carbon dioxide equivalent.
- It is the amount of CO₂ that would equate to a given amount of other greenhouse gas.
- To calculate, multiply the emissions of a gas by the gas's GWP.
- GWP played this role in the Kyoto Protocol.

Question

1 million metric tons of N_2O was emitted in 2010. The GWP of N_2O is 310. What is the CO_2 equivalent of N_2O emissions in 2010?

Answer

- 1 million metric tons of N_2O is the CO_2 equivalent of 310 million metric tons.
- 1 million metric tons of N_2O has the same effect on climate change as 310 million metric tons of CO_2 .



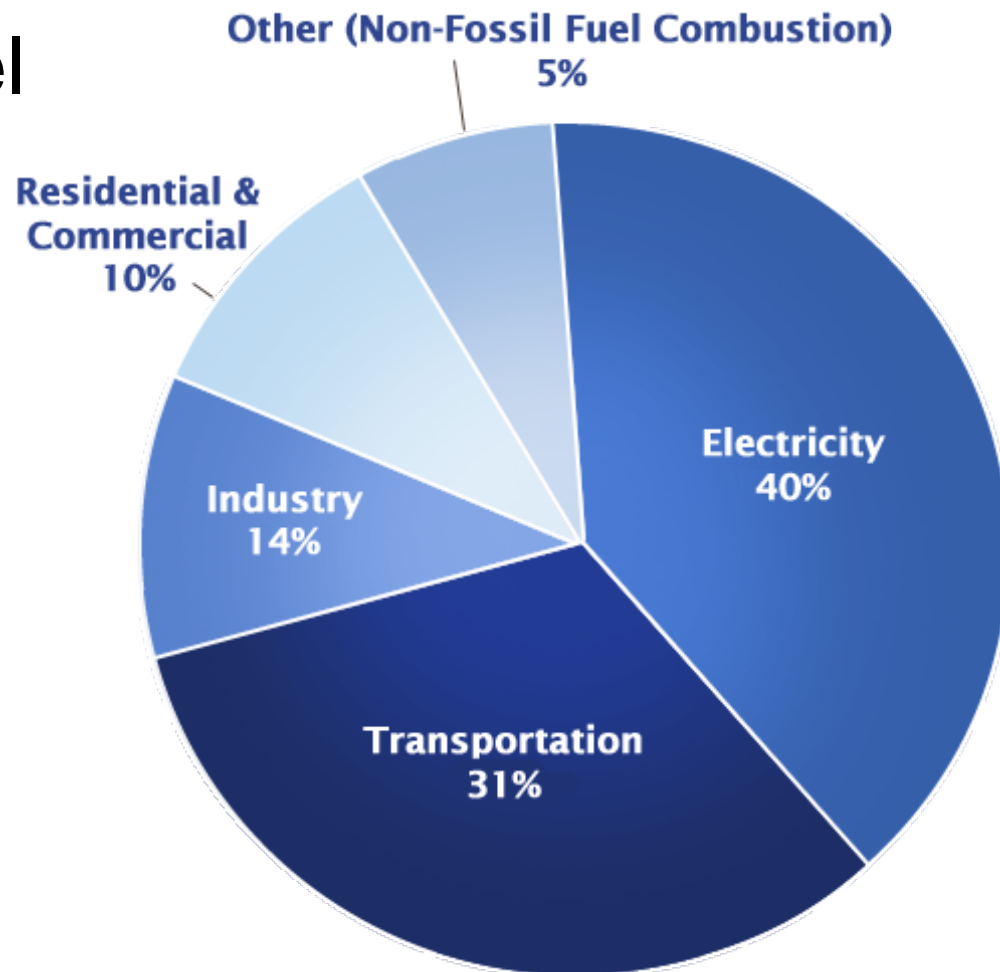
Total US GHG Emissions in 2010 = 6,822 Million Metric Tons of **CO₂** equivalent

Main Greenhouse Gases and their GWPs

- Carbon Dioxide (CO₂)
 - GWP: 1
- Methane (CH₄)
 - GWP: 21-25
- Nitrous Oxide (N₂O)
 - GWP: 298-310
- Fluorinated Gases (HFCs, PFCs, SF₆)
 - GWP:
 - HFCs: 140-11,700
 - PFCs: 6,500-9,200
 - SF₆: 23,900

US Carbon Dioxide (CO₂) Emissions 1990-2010

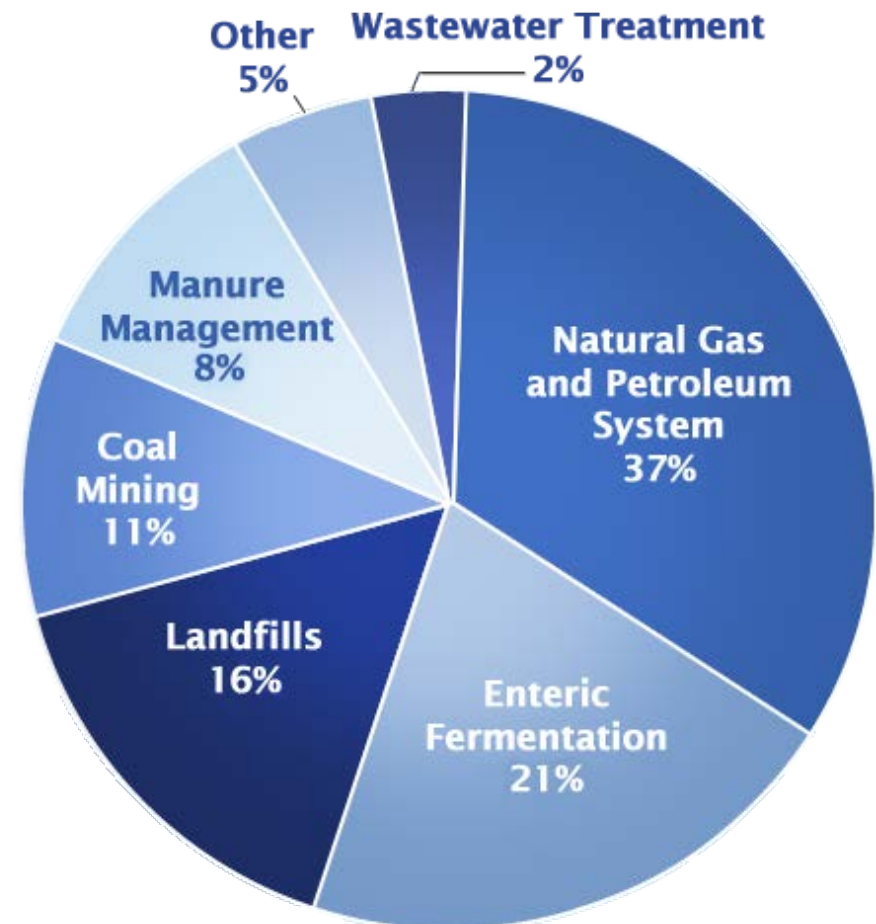
- 95% from fossil fuel combustion



2010 Emissions: 5,700 million metric tons

US Methane (CH₄) Emissions 1990-2010

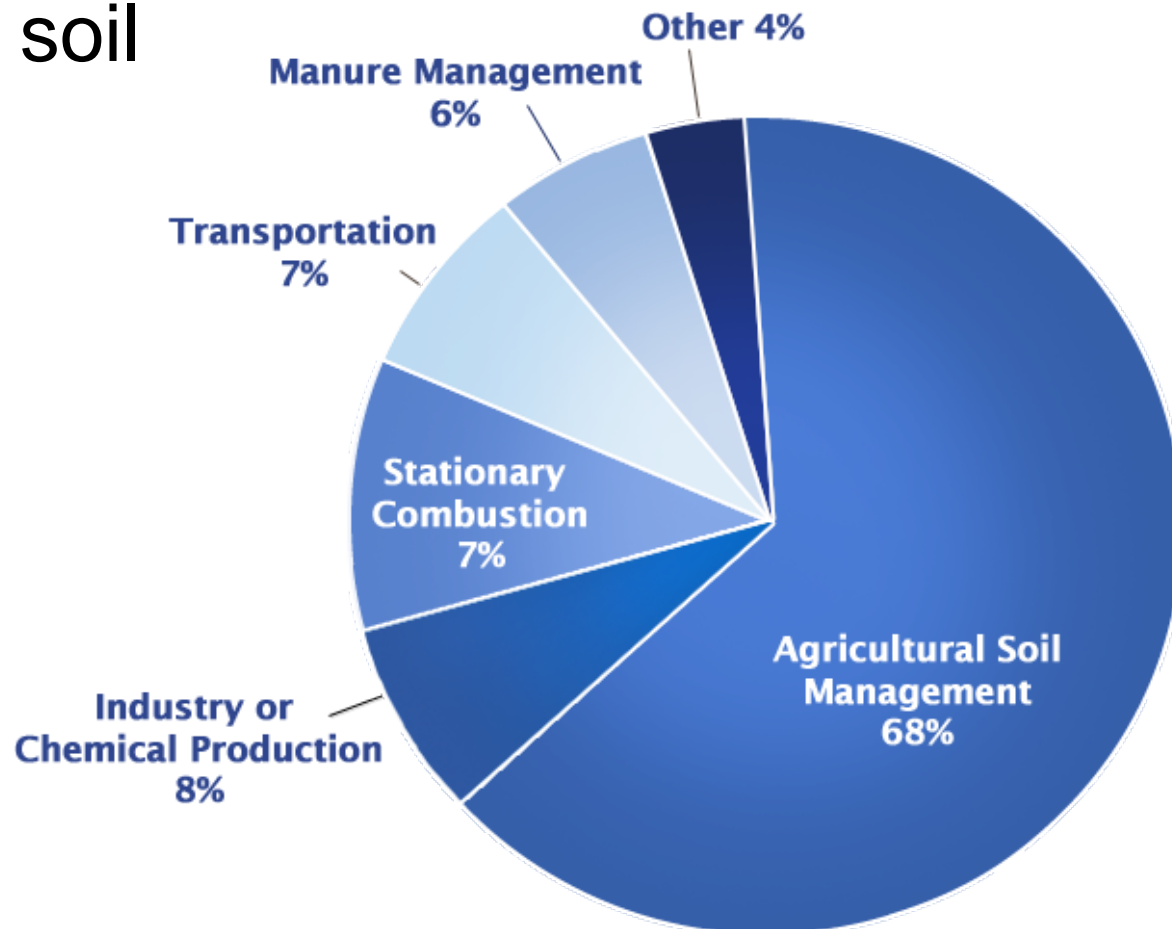
- Industry: Fossil fuel extraction, processing, and combustion.
- Agriculture: Domestic livestock digestion process; waste decomposition



2010 Emissions: 680 million metric tons (CO₂ equivalent)

US Nitrous Oxide (N₂O) Emissions 1990-2010

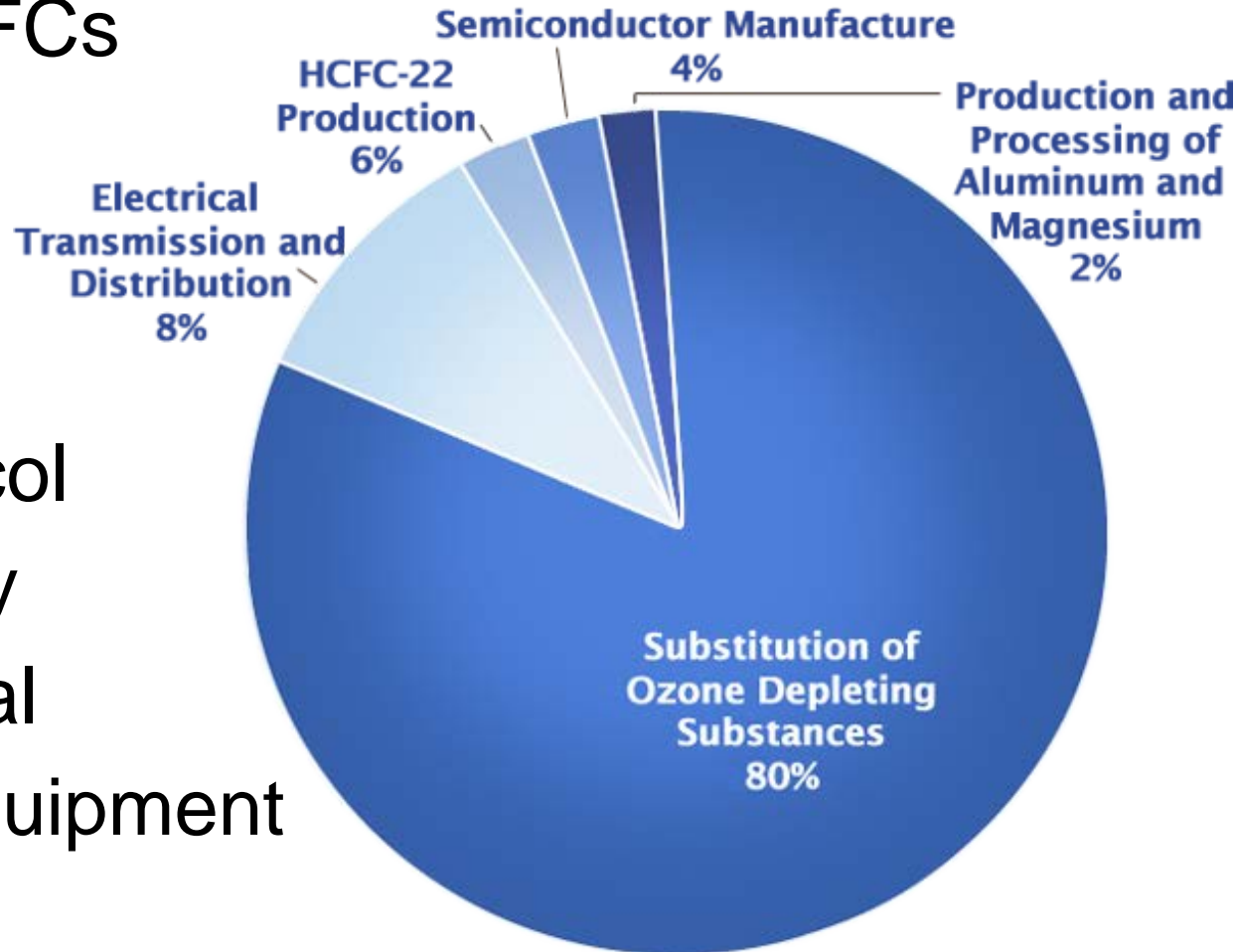
- 68% from soil fertilization



2010 Emission: 310 million metric tons (CO₂ equivalent)

US Fluorinated Gas Emissions 1990-2010

- HFCs and PFCs replace CFCs and HCFCs following the Montreal Protocol
- SF₆ is mainly used in electrical transmission equipment



2012 Emissions: 140 million metric tons (CO₂ equivalent)

High GWP vs. Global Warming Impact

- SF₆ has an astronomical GWP of 23,900
- Does that mean this gas has a large influence on the warming of the planet?
- No, despite its potential to warm the planet, its uses are limited to specialized technical applications and "emissions" are really more like leakage
- Then what does GWP tell us about SF₆?

Policy Implications

- GWP time horizons are a policy decision
 - 20 Years
 - 100 Years
 - 500 Years
- Different time horizons require different abatement strategies

GWP values and lifetimes from 2007 IPCC	Lifetime (years)	GWP time horizon		
		20 years	100 years	500 years
<u>Methane</u>	12	72	25	7.6
<u>Nitrous oxide</u>	114	289	298	153
<u>HFC-23 (hydrofluorocarbon)</u>	270	12,000	14,800	12,200
<u>HFC-134a (hydrofluorocarbon)</u>	14	3,830	1,430	435
<u>Sulfur hexafluoride</u>	3200	16,300	22,800	32,600

Methane

- 20 year GWP is 72
 - Landfill emissions = 20% of US coal emissions
- Growth of natural gas industry
 - Methane can be emitted as the result of leaks and losses during transportation or during combustion
 - Over the past decade demand has increased by 2.7% per year
- Large dams emit 104 million metric tonnes of methane annually from reservoir surfaces, turbines, spillways and rivers downstream

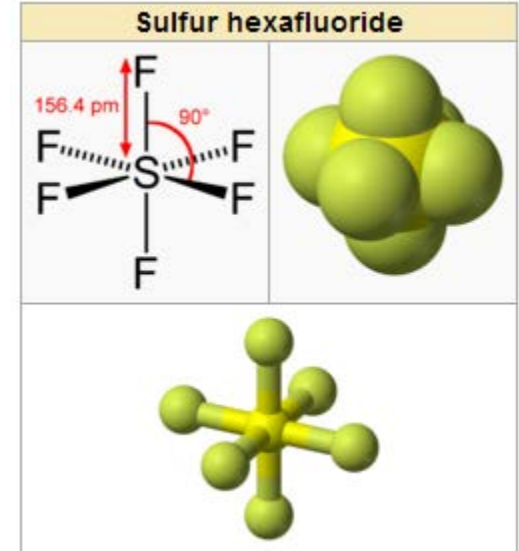
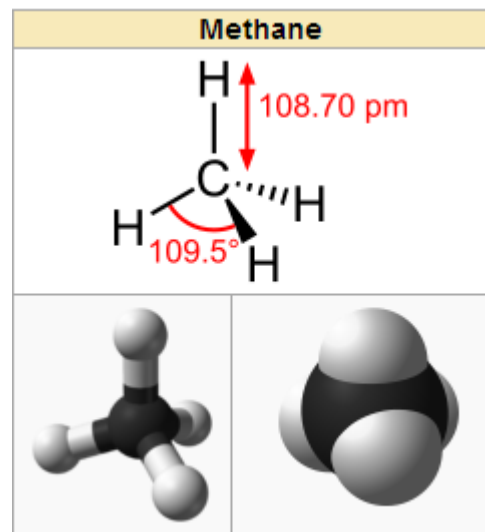
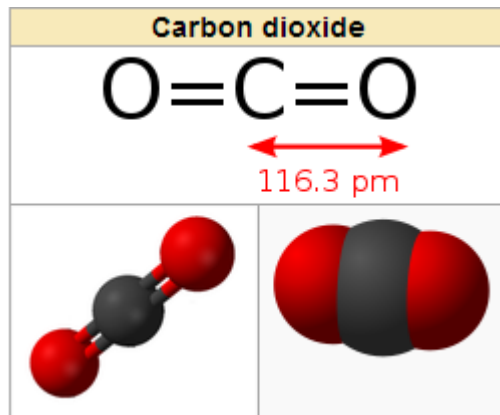
Nitrous oxide

- In 2008, cropland contributed nearly 69% of total direct nitrous oxide (N₂O) emissions
- Agriculture contributed 6.1% of the total U.S. greenhouse gas emissions
- Emissions from agricultural soils were 6% higher in 2008 than 1990

The Future of Refrigerants

- Low global warming potential (LGWP)
 - “Natural” refrigerants
 - Carbon dioxide (CO₂)
 - Hydrocarbons (HC)
 - Ammonia (NH₃)
 - HFOs and HFO/HFC blends
 - Trade offs between
 - GWP
 - Energy efficiency
 - Safety
 - Cost

Now that you know a bit more...



Which one is it?