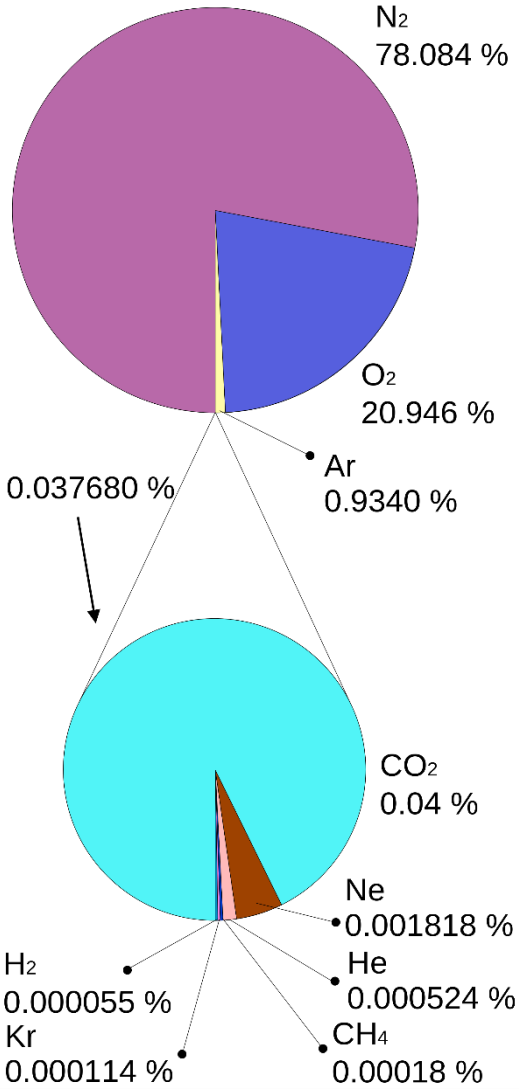
Chemistry of the Global Climate

1. Composition of Earth's Atmosphere
2. Radiative Energy Balance
3. Greenhouse Gases and Aerosols
4. Radiative forcing and global warming potentials (GWP)
5. Energy Resources Fossil and Renewable

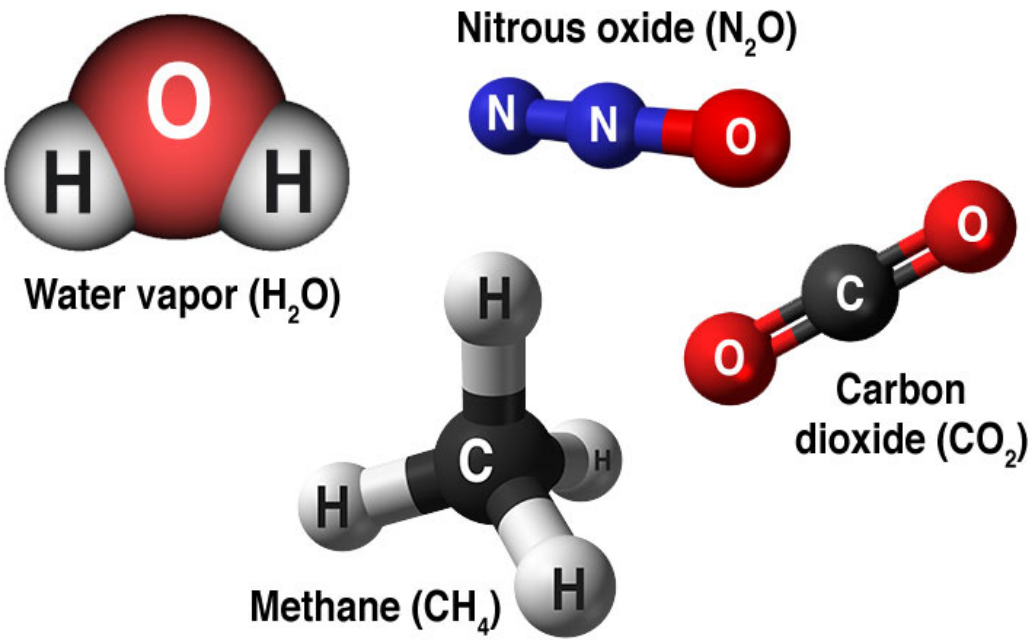
1. Atmospheric composition

Mixing ratios of present day dry Earth atmosphere

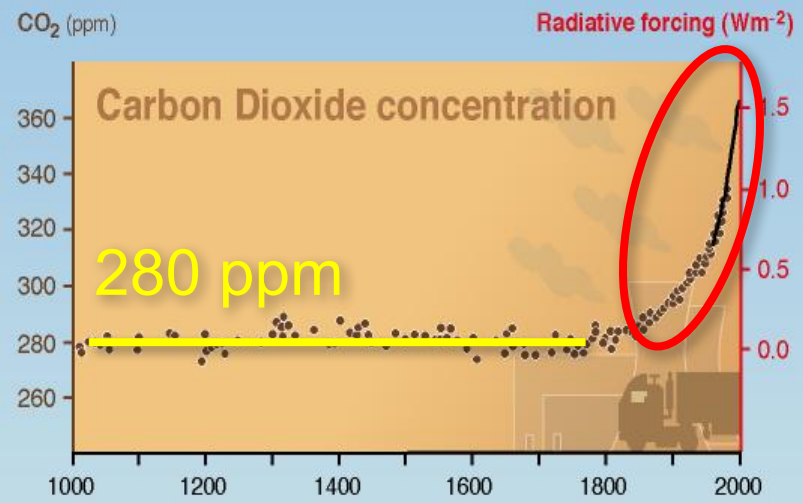
Nitrogen	78.08 %
Oxygen	20.95 %
Argon	0.934 %
Carbon dioxide	~400 ppm_v (increasing)
Neon	18.2 ppm_v
Helium	5.24 ppm_v
Methane	~1.8 ppm_v (increasing)
Krypton	1.14 ppm_v
Hydrogen	0.5 ppm_v
Nitrous oxide	~0.3 ppm_v (increasing)
Xenon	0.09 ppm_v

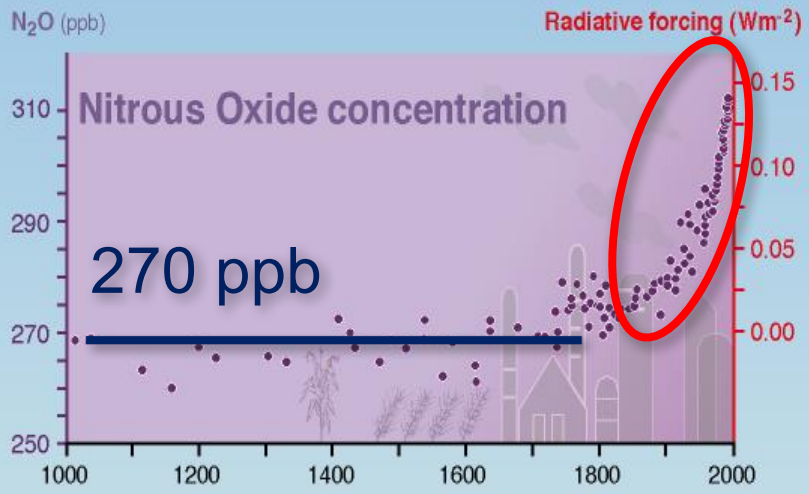


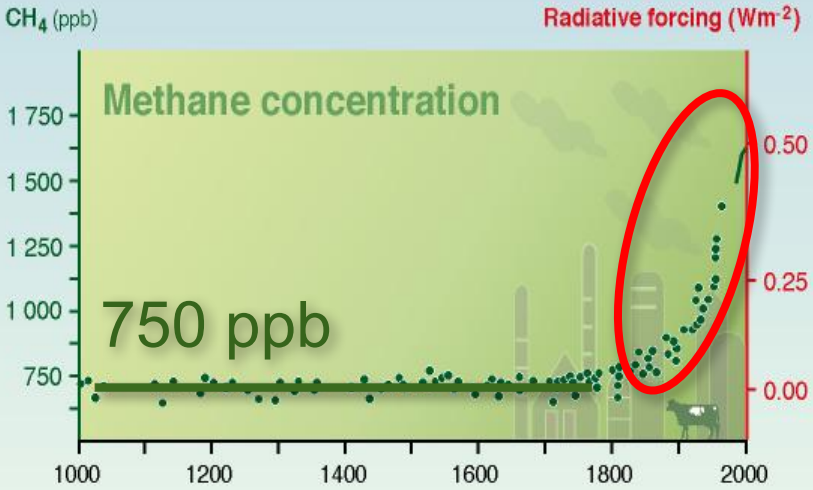
Major ‘Greenhouse’ Gases

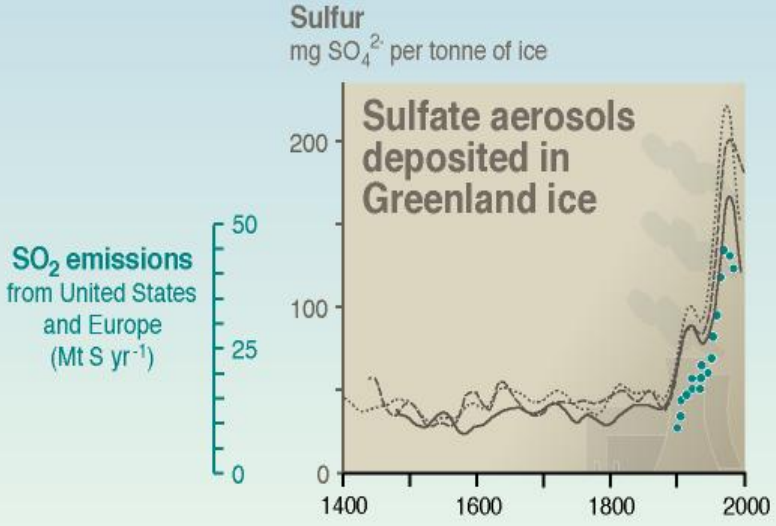


Changes in Atmospheric Composition

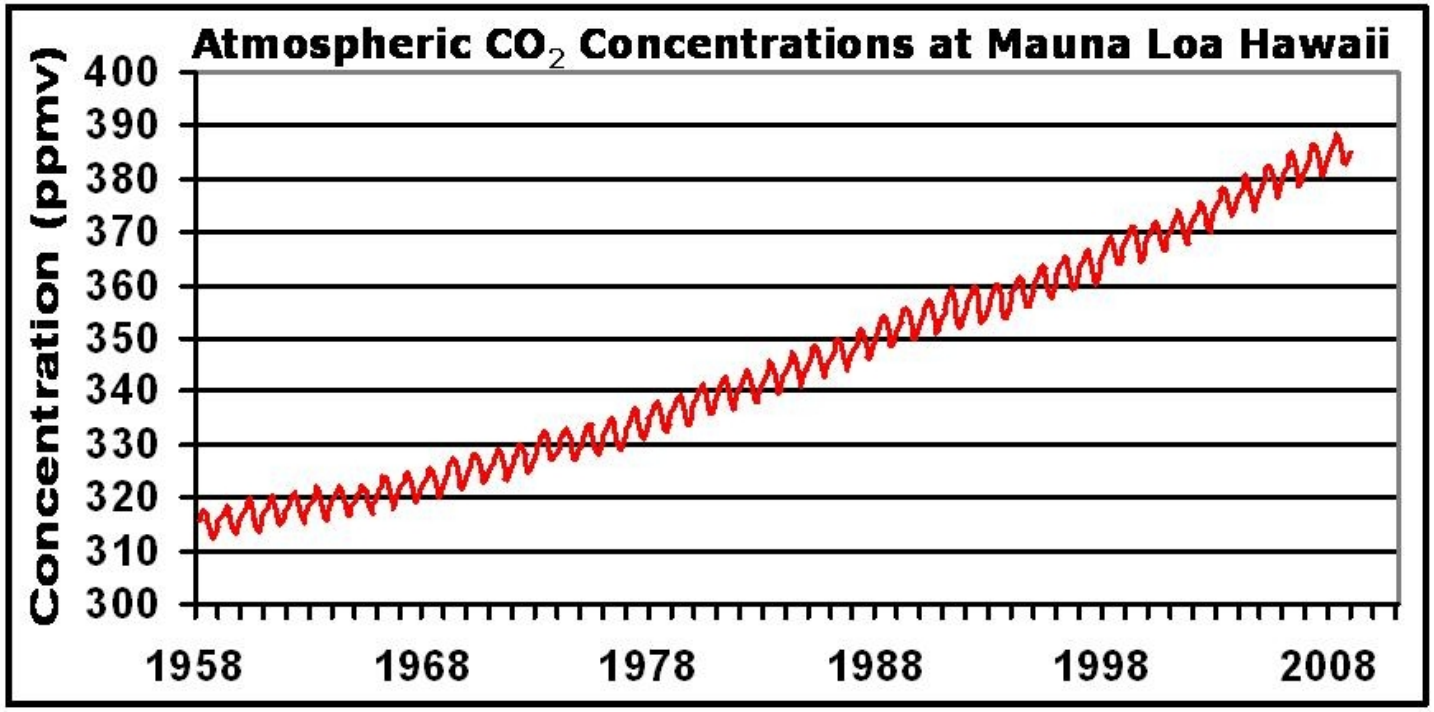




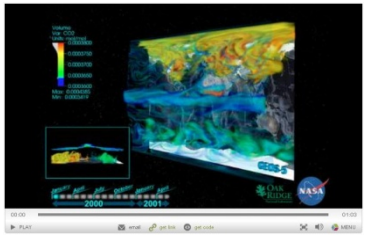




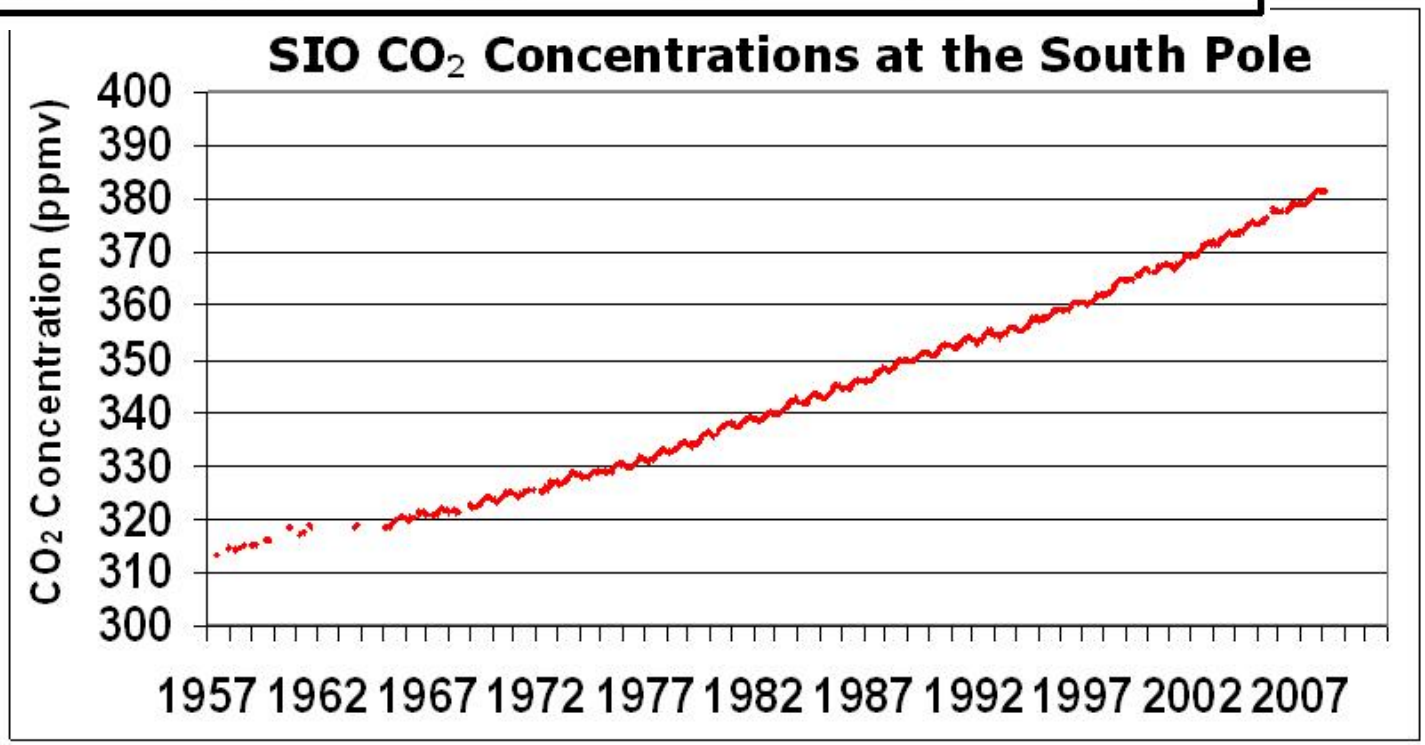
Adapted from IPCC third assessment report, 2007



CDIAC, 2010



Go to NASA/Oak Ridge Video



How Much CO_2 in ppm Does a Barrel of Oil Produce?

Basic Facts:
- Carbon-based fuel releases 3.15 times its mass in CO_2
- Mass of a barrel of oil is about 135 kg
- 1 barrel releases 425 kg CO_2
- CO_2 has a molar mass of 44g/mol

1 barrel releases 425 kg of CO_2, in moles this is

$$\frac{425\,kg}{0.044\,kg\,/\,mol} = 10^4\,mol$$

Since the atmosphere contains 1.7 X 10^{20} mol of air, one barrel will release

$$\frac{10^4}{1.7\times10^{20}} = 6\times10^{-17}$$

This is the fraction of CO_2 relative to the entire atmosphere – multiply by 1 million to get the parts-per-million or ppm. So, 1 barrel releases an additional

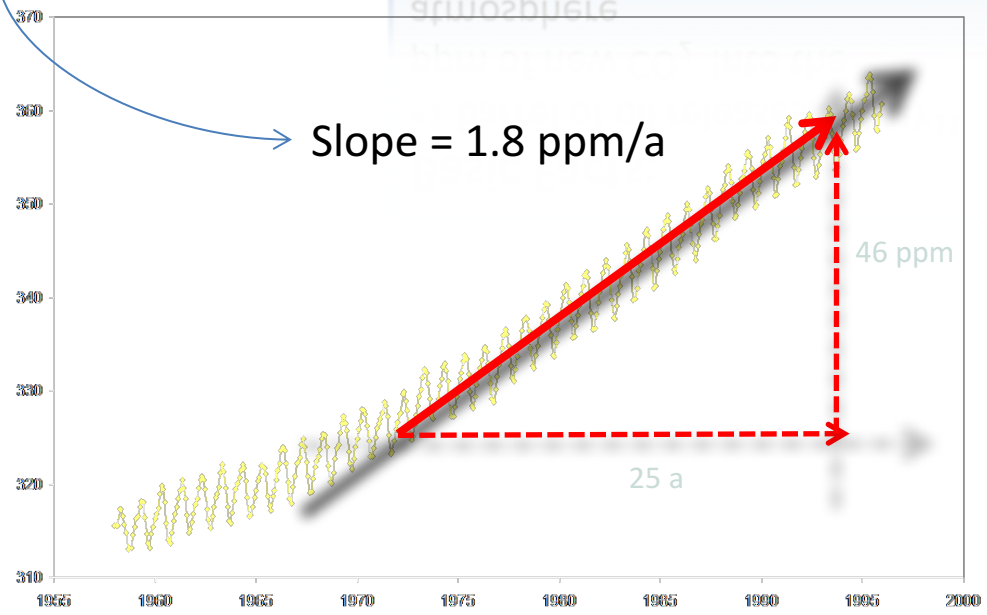
$$6\times10^{-11}\,ppm$$

Is the observed increase in CO_2 "natural" or …

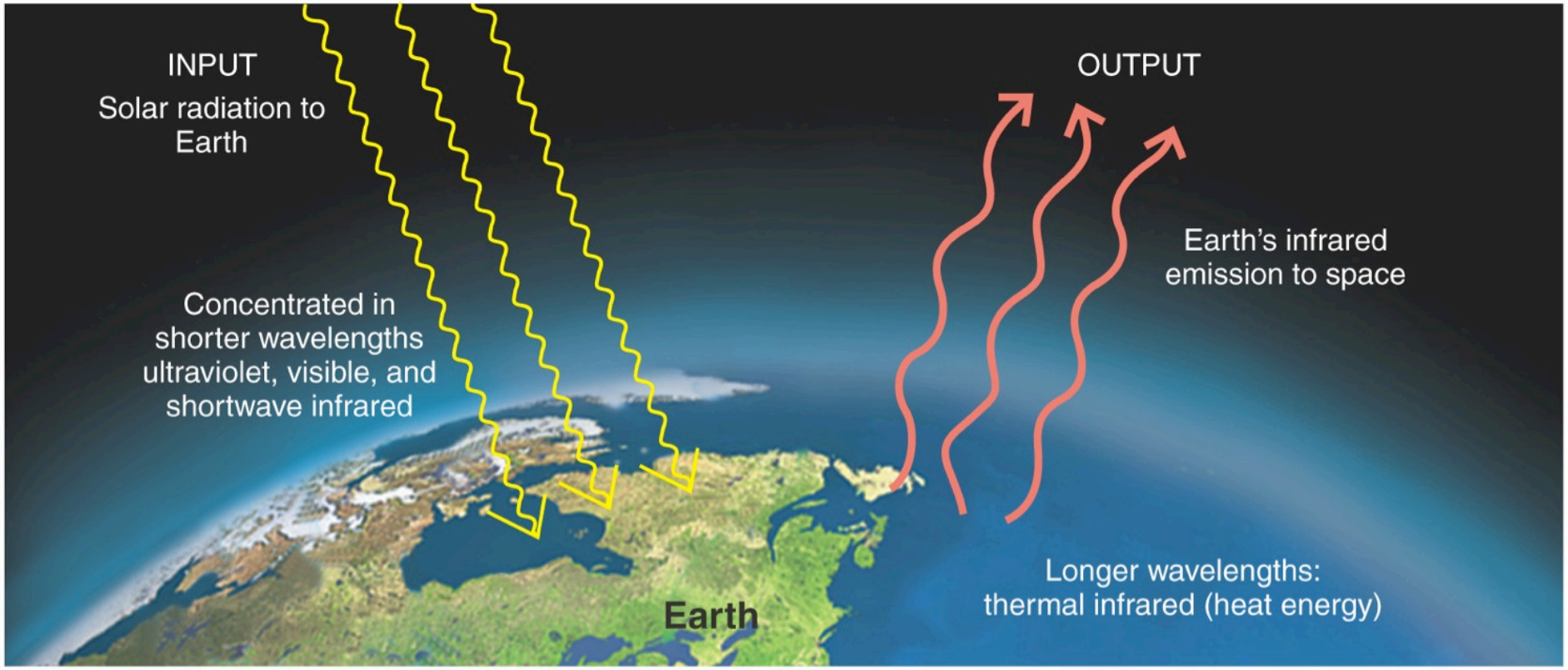
$$(30 \times 10^{9}\ bbl/a)(6 \times 10^{-11}\ ppm/bbl) = 1.8\ ppm/a$$

Basic Facts:

- 1 barrel of oil releases 6 X 10^{-11} ppm of new CO_2 into the atmosphere
- 30 billion barrels of oil are consumed annually

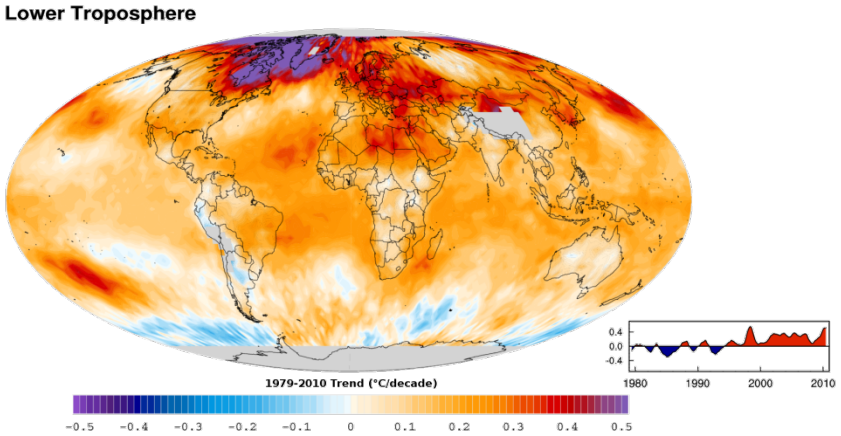


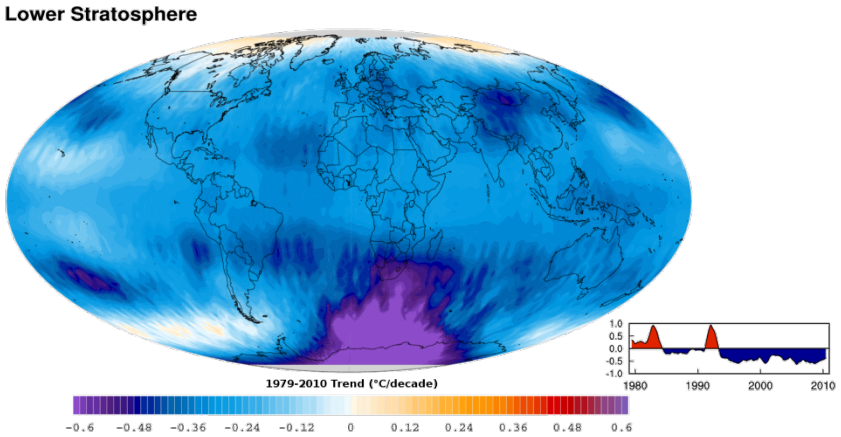
2. Radiative Energy Balance

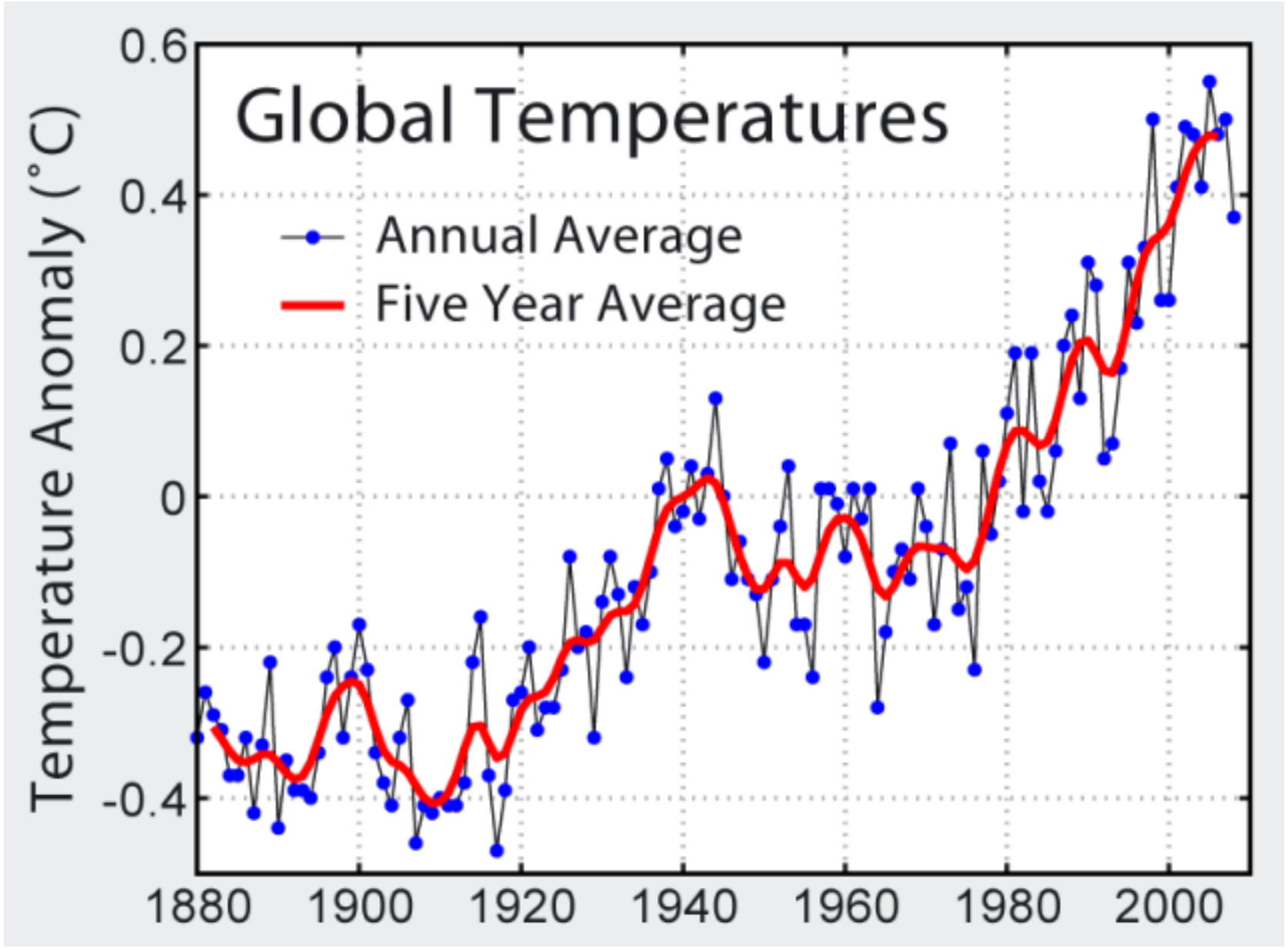


Observational Evidence for an Enhanced Greenhouse effect

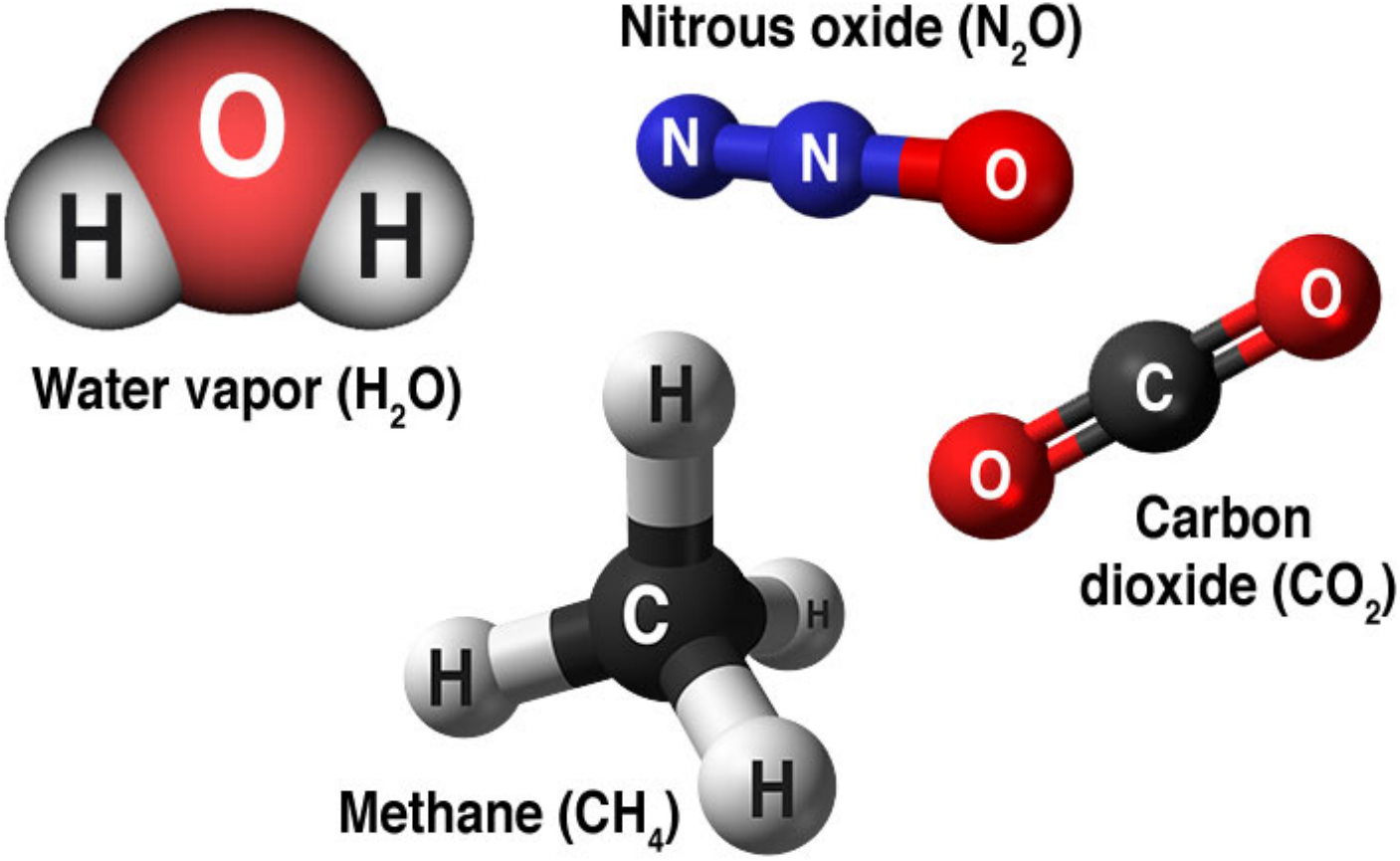
Tropospheric warming and stratospheric cooling






Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
1880
1900
1920
1940
1960
1980
2000

3. Greenhouse Gases and Aerosols



CO_2 –Temperature Feedback Loops

Decreasing solubility in water

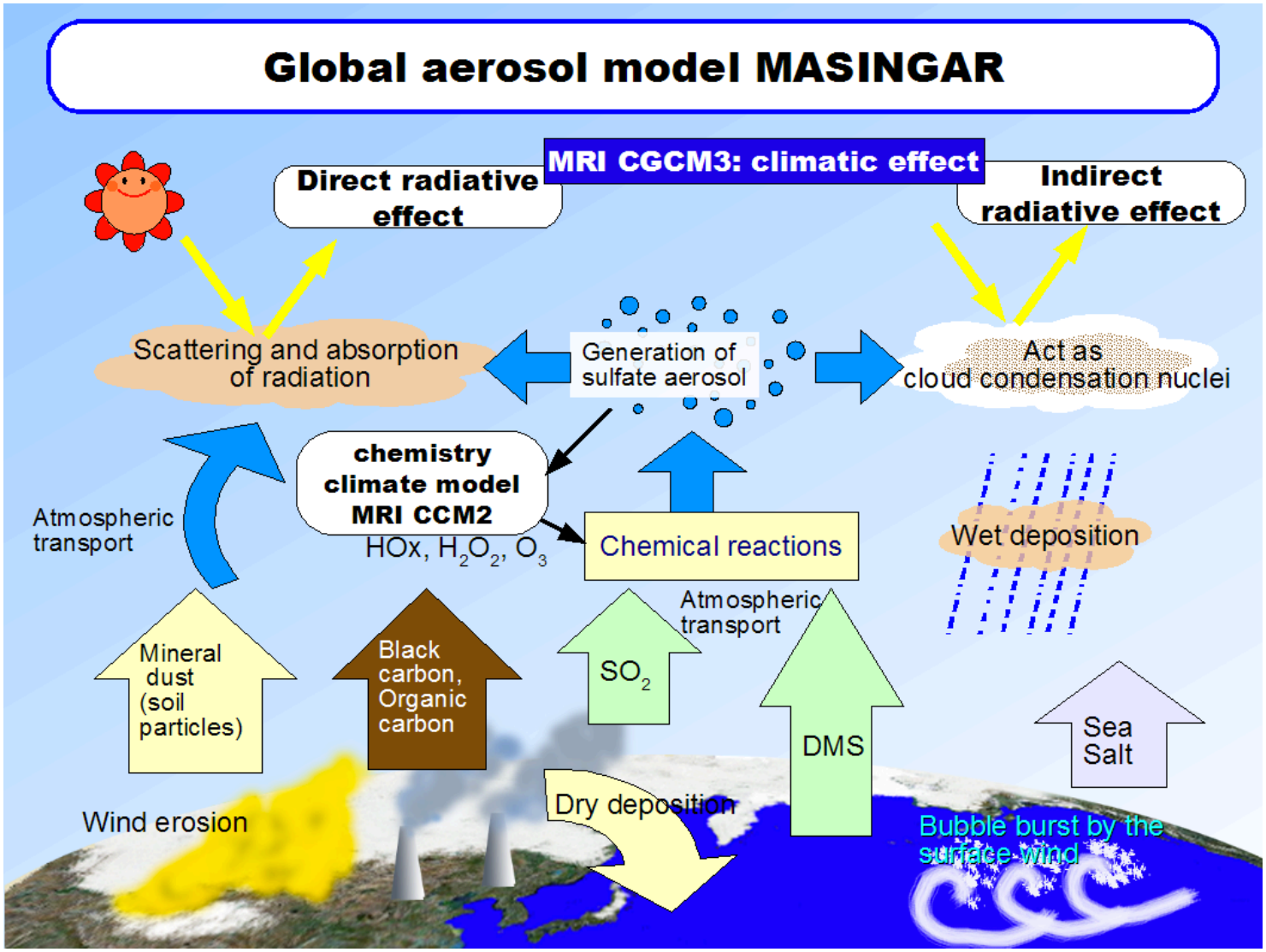
Increasing biomass production

H_2O –Temperature Feedback Loops

Increased evaporation of water

Increasing Albedo

Aerosol Models



4. Radiative Forcing and GWP

Three factors to rank immediate relative importance of GHGs

1) Current atmospheric concentrations

2) Wavelength of IR absorption bands

3) Strength of IR absorption per molecule

Long term impact also requires atmospheric residence time (τ)

Definitions

Radiative forcing

($W\ m^{-2}$)

Radiative forcing or climate forcing is the difference between insolation (sunlight) absorbed by the Earth and energy radiated back to space.
The influences that cause changes to the Earth's
climate system altering Earth's radiative equilibrium, forcing temperatures to rise or fall, are called climate forcings.

Relative instantaneous radiative forcing

(relative to equivalent mass of CO_2)

Global warming potential

(relative to equivalent mass of CO_2 over specified time)

Radiative Forcings and GWPs

	RF (W/m^2)	RRIF	τ (yr)	GWP - 100 yr
CO_2	1.7	1	50-100	1
CH_4	0.48	25	12	28-36*
N_2O	0.16	220	114	265-298
O_3	0.30			
CFC-12		23,000	100	10,900
HCFC-22		14,000	12	1,810
CCl_4		9,300	26	1,400
aerosols	-1.2 +/- ?			

* Shine, K.P. et al., Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing, *Geophysical Res. Lett.*, 43(24), 12,614-12,623 (**2016**).

Anthropogenic GHG

emissions and relative instantaneous forcing

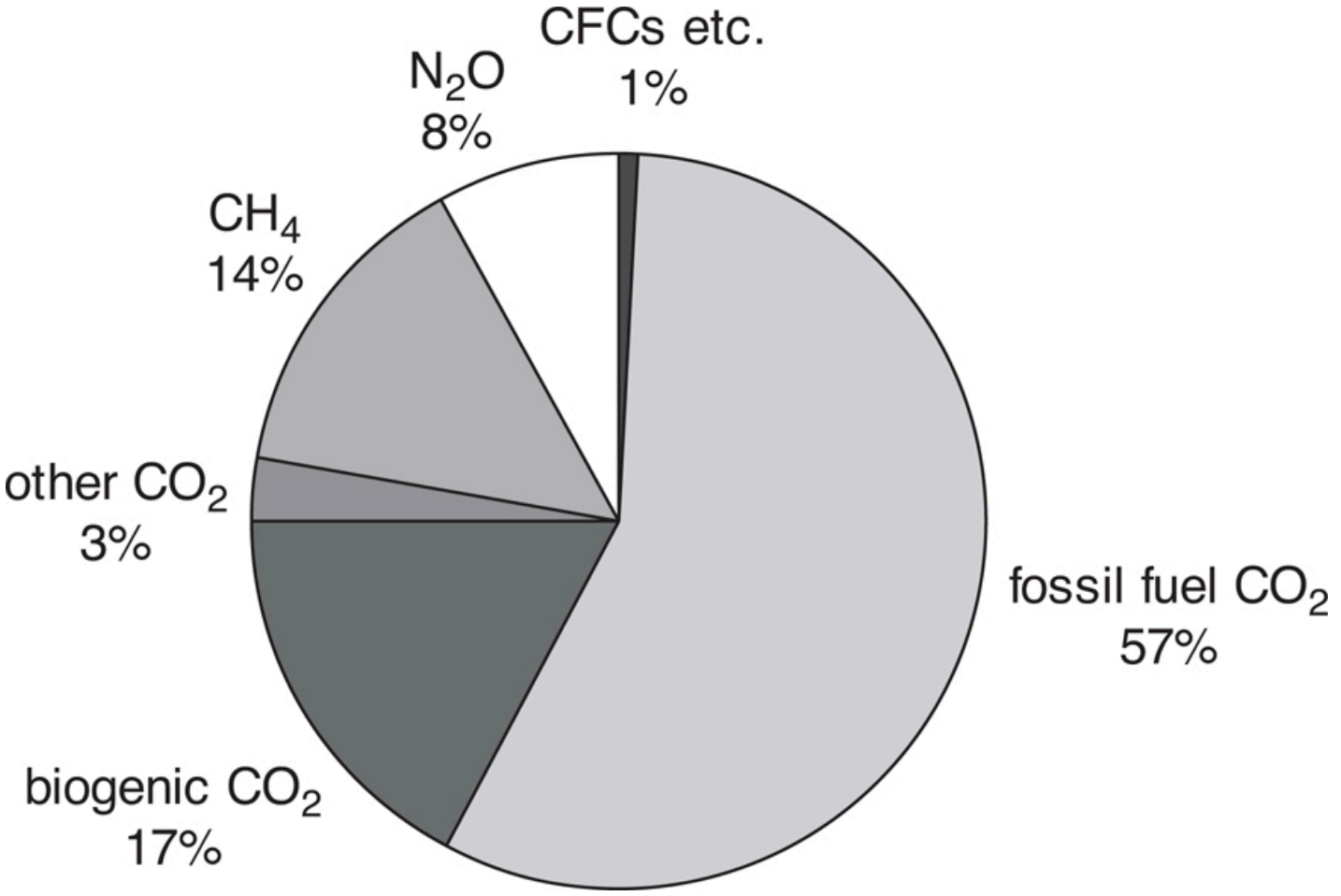
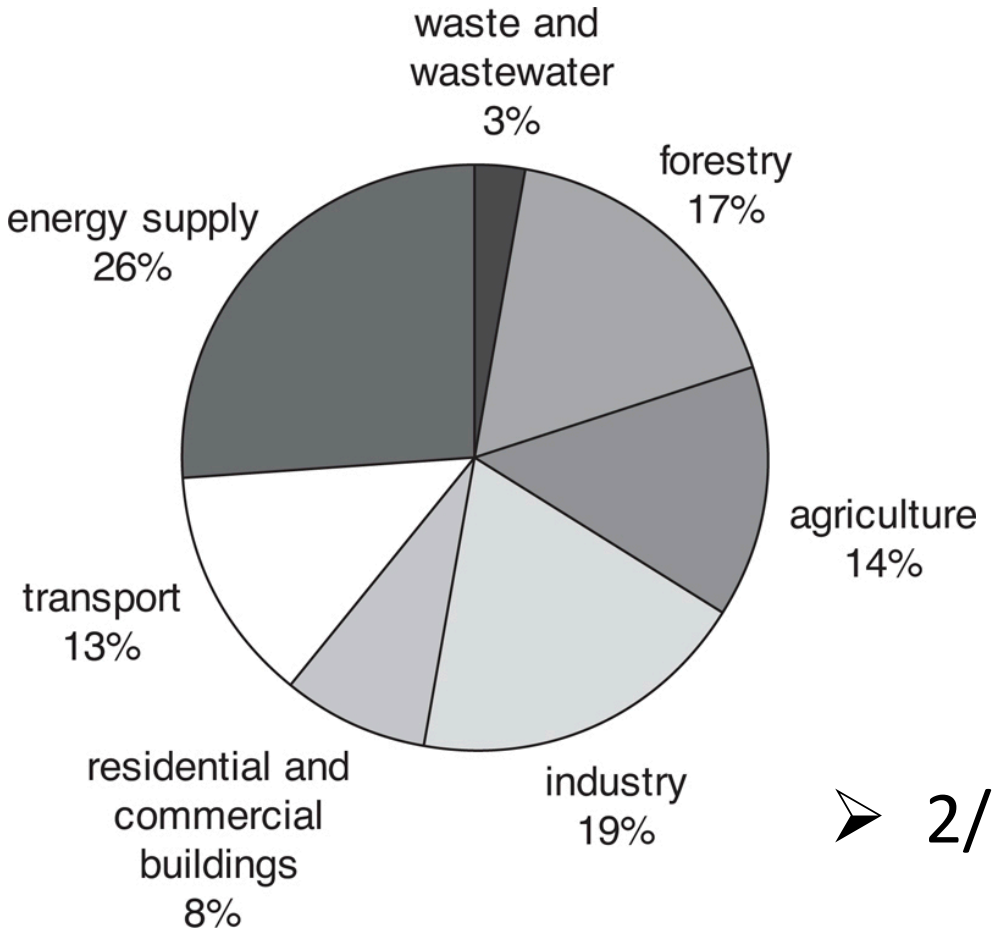


Fig 8.13 (van Loon)

5. Energy Resources

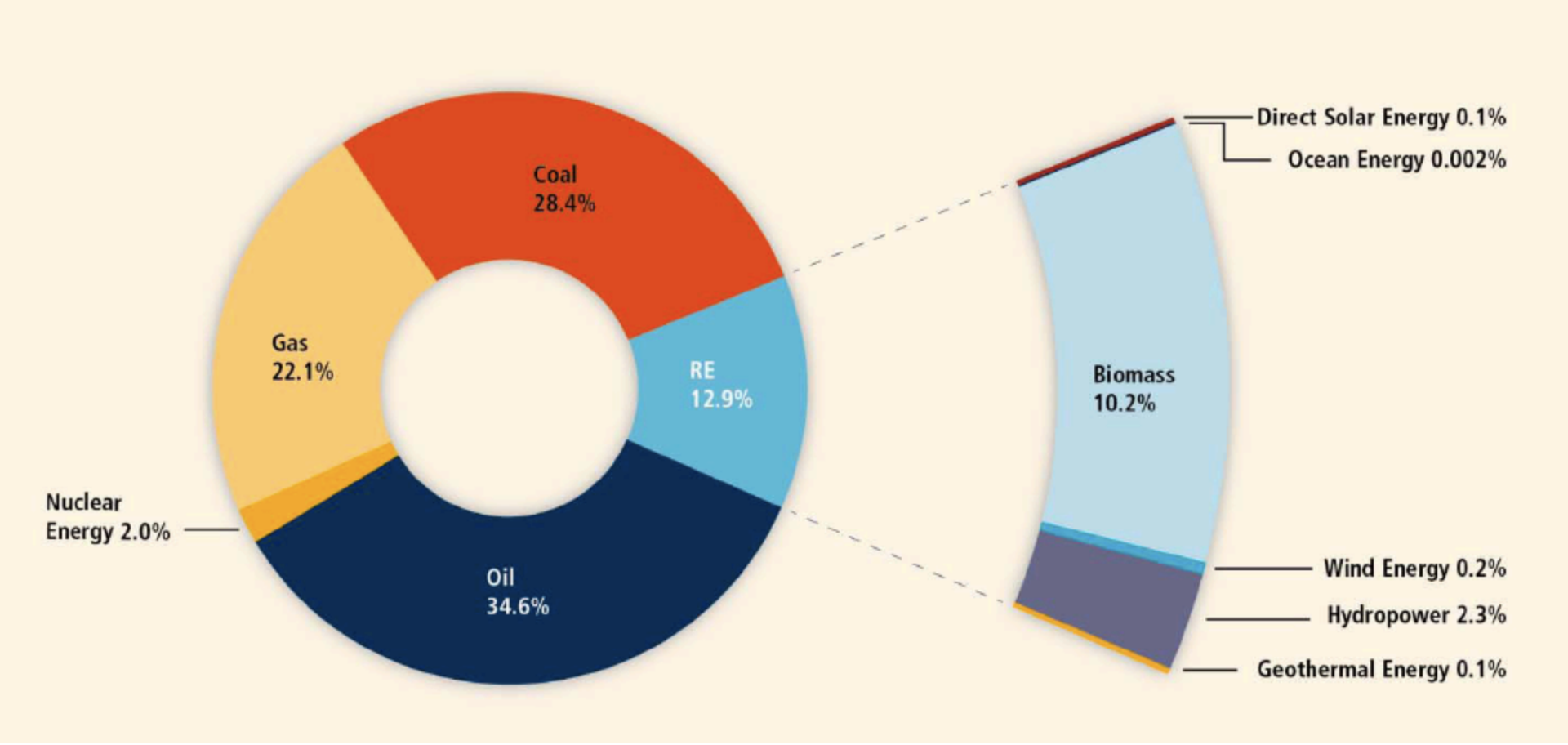
Anthropogenic GHG Emissions
(CO_2 – equivalents)



- 2/3 energy related

Fig 8.12 (van Loon)

World Energy Consumption



Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), IPCC, May, 2011.

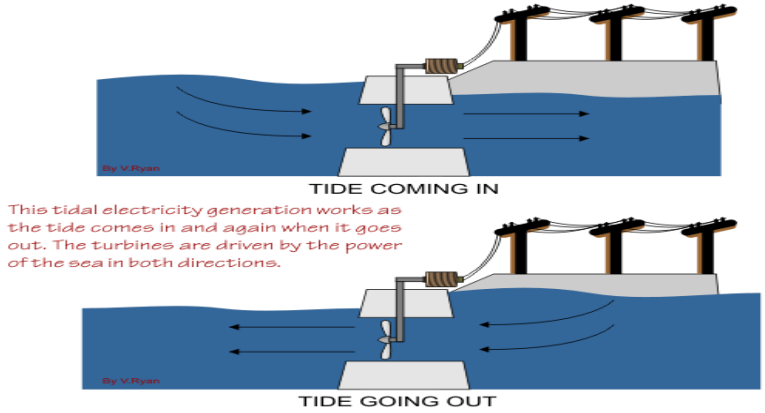
Renewable Energy Sources

Wind Power

Solar Thermal

Photo Voltaics

Tidal Power



Global Energy Demands

Current use	~ 14 TW
Future use (2050)	~ 30 TW

Global Resource Estimates (best case scenarios)

Tidal/Oceans	~ 2 TW
Hydro	~ 2 TW
Wind (10 m)	~ 4 TW
Biomass (all crops)	~ 7 TW
Nuclear (Fission)	~ 8 TW (200/yr forever)
Geothermal	~ 12 TW

Solar 120,000 TW (incident) ~ 800 TW(practical)

Lewis, N.S. & Nocera, D., *PNAS*, 2006, 103:15729