

GHGs and Human Emissions

How's your driving record? Clean? It's clean, real clean.
Like my conscience. — Travis Bickle.

Ivo Welch

2023-02-17

Measuring Emissions in GtCO₂

- ▶ **GtCO₂**: Gigatonne of CO₂ (per year):
 - ▶ equivalent, 1,000,000,000 metric tonnes.
 - ▶ We will work with $\approx 1\text{--}50$ GtCO₂.

- ▶ Be careful: 1 GtC (carbon) is *not* 1 GtCO₂:
 - ▶ The difference is oxygen.
 - ▶ 1 tC = 3.5 tCO₂ .
 - ▶ *Social Cost of Carbon* is badly misnamed. The quoted \$-figures are really the *Social Cost of Carbon-Dioxide* (CO₂).

Burnt Carbon: 10.5 GtC



Emitted CO₂: 38 GtCO₂



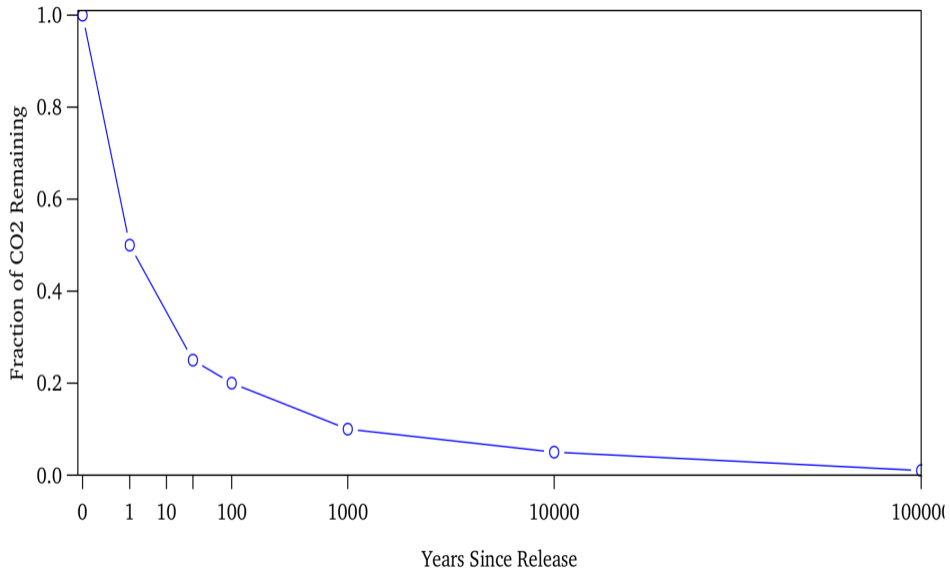
Atmosphere

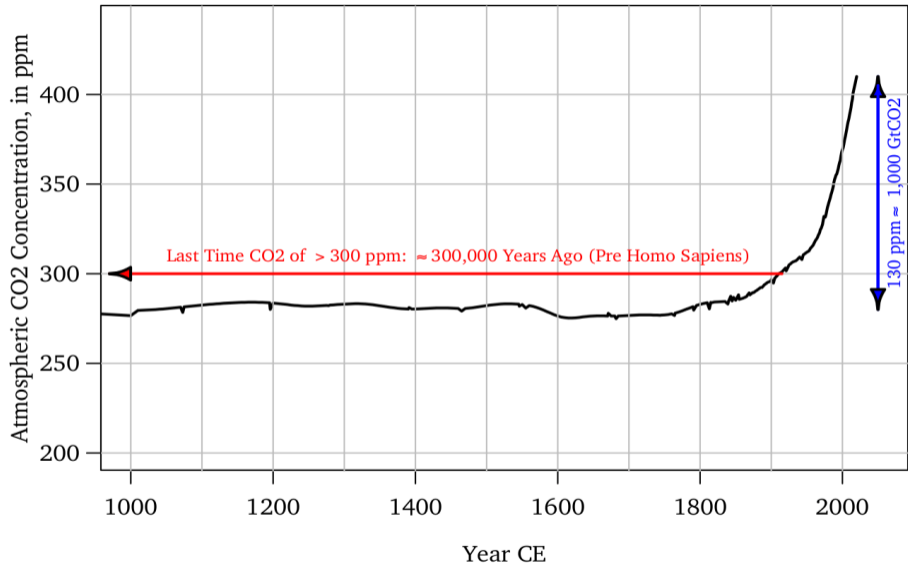


System State
← (Temperature,
Buffers, etc.)

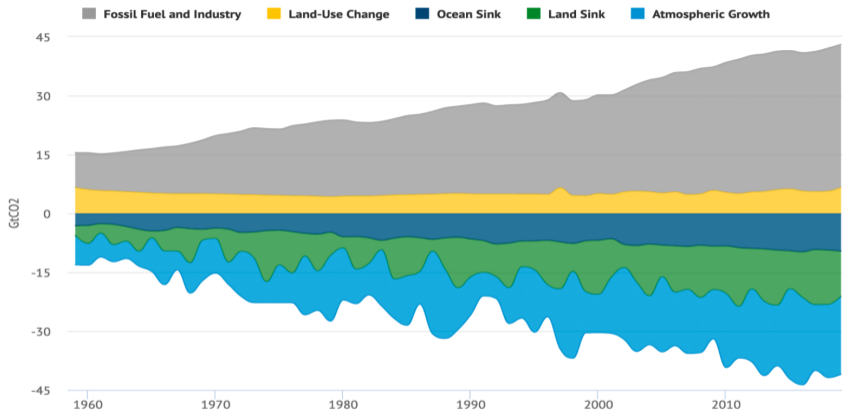
Land Sinks: 10 GtCO₂

Ocean Sinks: 10 GtCO₂





Global Carbon Budget, 1959-2019



Annual global carbon budget of sources and sinks from 1959-2019. Note that the budget does not fully balance every year due to remaining uncertainties, particularly in sinks. 2019 numbers are preliminary estimates. Data from the [Global Carbon Project](#); chart by Carbon Brief using [Highcharts](#).

- ▶ we hope carbon sinks won't exhaust.
 - ▶ e.g., warmer oceans may bubble out more CO₂
- ▶ fortunately, no signs of net exhaustion *yet*
- ▶ unknown: could also ramp up (e.g., plants)

Long-Lived GHG Emissions

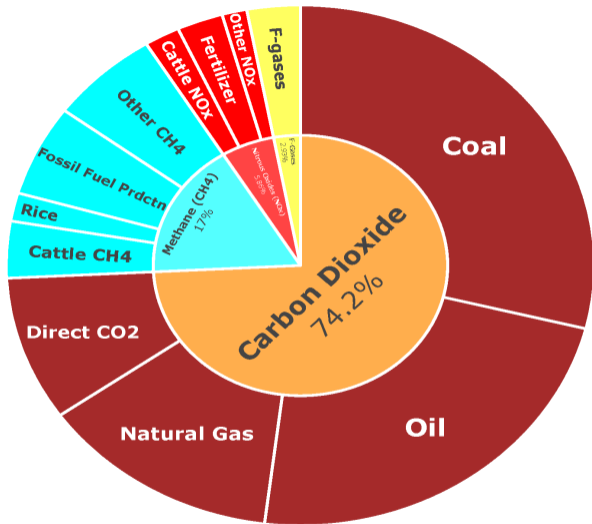
Highly correlated (many even from same sources):

- ▶ CO₂ (3/4 of GHG, longest-term).
- ▶ Methane CH₄ (1/8 of GHG).
 - ▶ Much more opaque to IR
 - ▶ immediate control has big short-term payoffs.
 - ▶ CH₄ decays to \approx minute CO₂.
- ▶ Other (NO_x, CFC).

Global Warming Potential (GWP)

- ▶ CH₄ warms more, but doesn't last as long.
- ▶ CO₂: GWP=1.
- ▶ **GtCO₂e**: measure of warming power
- ▶ We use **standard GWP factors**.

Factors can be argued with, depending on use case, but good enough for us.



Land Charge

- ▶ (Human) land charge (per year) is reduced (forest) absorption of CO₂.
- ▶ **Carbonbrief** suggests that the land use charge has declined enough to offset emission *increases* for about one decade now.
- ▶ Good news...but needs to be checked.
- ▶ And how much longer will this be the case?

Water Vapor

- ▶ Think air humidity.
- ▶ $\approx 3/4$ of greenhouse warming.
- ▶ Not long-lived.
- ▶ Very responsive to temperature
 - ▶ Positive feedback amplification.
 - ▶ Likely fully (100%) driven by long-lived GHGs.
 - ▶ A scientific minority disagrees (90%?).
- ▶ but also (mostly) responsible for clouds

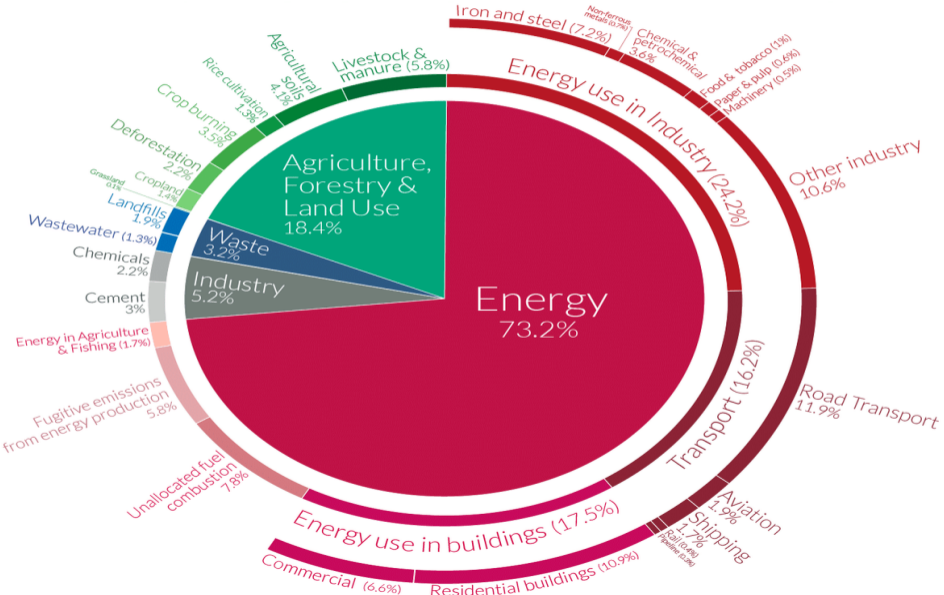
World GtCO₂ Fuel Emissions (Only CO₂)

From	GtCO ₂
Coal	15
Oil	12
Gas	7
Other	5
Total	38

Methane And NOx: GtCO₂

From	GtCO ₂ e
Cattle	3
Fossil Fuel	3
Rice	1
Fertilizer	1
Total	12

Circle Plot



GHG Sources

From	GtCO ₂ e
All = Power, Heat, Agriculture	50
Agriculture	10
Non-Agriculture	40
Combustion	33
Cement	10
Airplanes	2

From	GtCO ₂ e
Transport	8
Electricity	14
Heating	4
Industrial	16

Electrifying

- ▶ Think 25-35 GtCO₂e is easily electrifiable.
- ▶ Think 15-25 GtCO₂e is not (ag, flying, etc.)

Summary

- ▶ World GHG emissions are **huge**,
- ▶ and still **accelerating**,
 - ▶ although rate of acceleration (3rd derivative) is slowing.