GHGs and Human Emissions

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

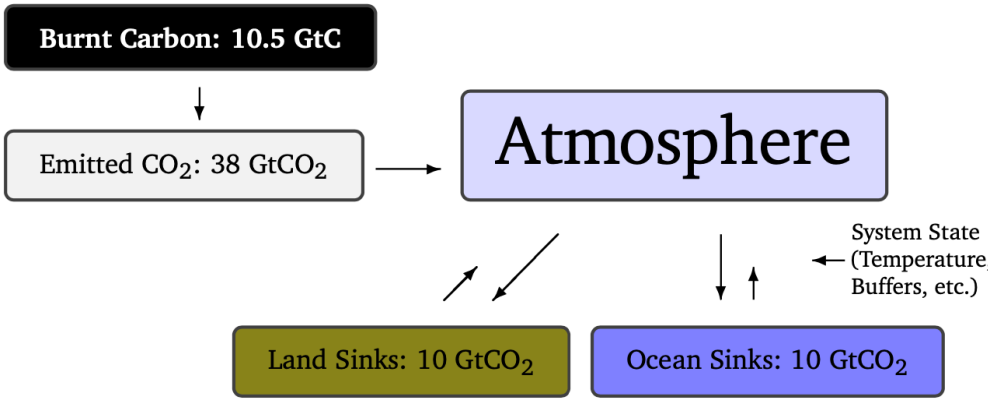
Ivo Welch

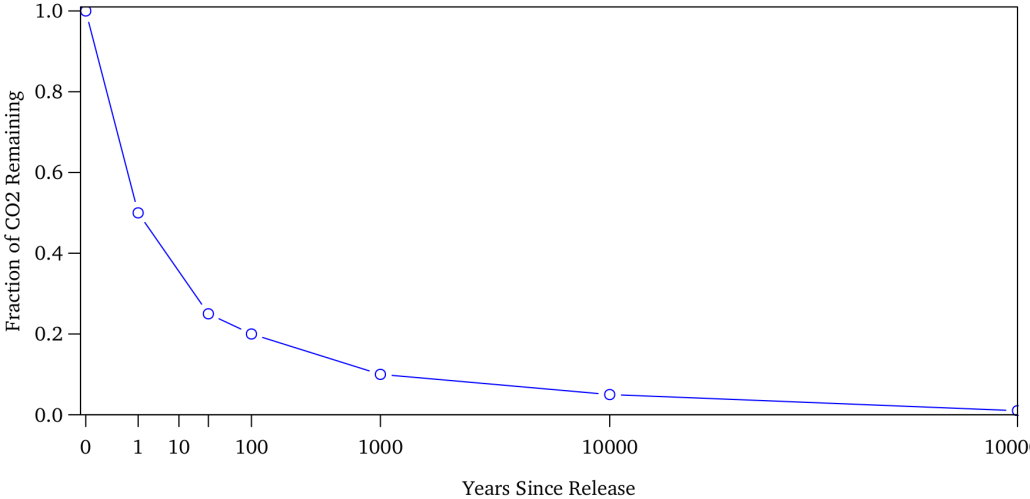
December 31, 2021

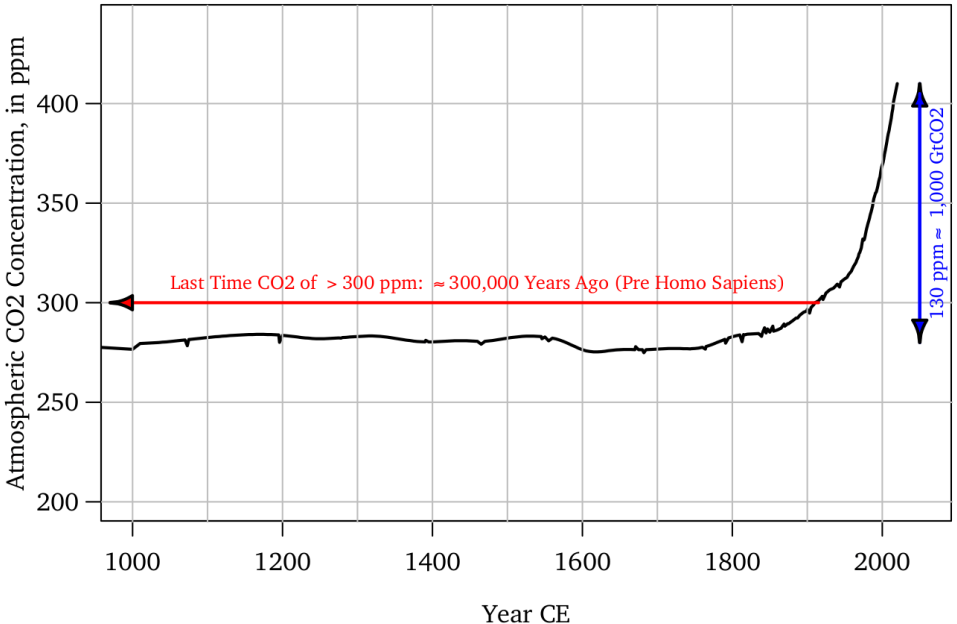
Measuring Emissions in $GtCO_2$

- **$GtCO_2$**: Gigatonne of CO_2 (per year):
  - equivalent, 1,000,000,000 metric tonnes.
  - We will work with $\approx$ 1–50 $GtCO_2$.

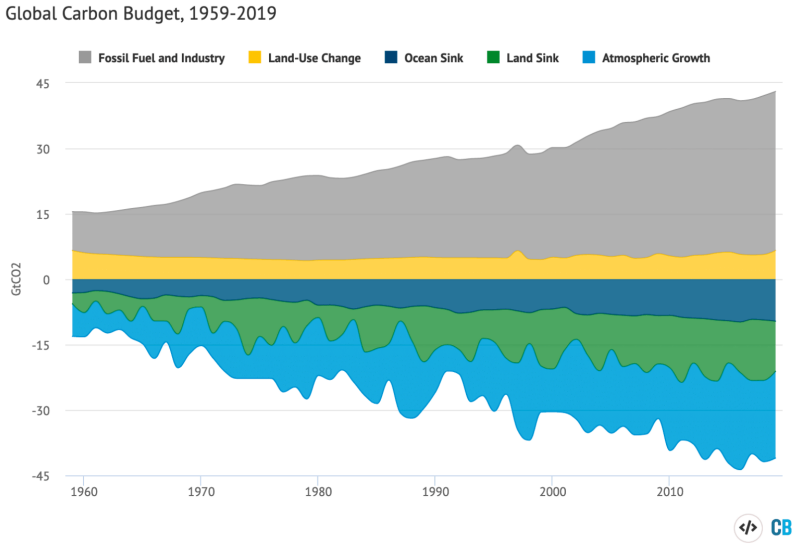
- Be careful: 1 GtC (carbon) is *not* 1 $GtCO_2$:
  - The difference is oxygen.
  - 1 tC = 3.5 tCO_2 .
  - *Social Cost of Carbon* is badly misnamed. The quoted $-figures are really the *Social Cost of Carbon-**Dioxide*** (CO_2).


Burnt Carbon: 10.5 GtC
Emitted CO_2: 38 $GtCO_2$
Atmosphere
System State
(Temperature,
Buffers, etc.)
Land Sinks: 10 $GtCO_2$
Ocean Sinks: 10 $GtCO_2$


1.0
0.8
0.6
0.4
0.2
0.0
Fraction of CO2 Remaining
0
1
10
100
1000
10000
Years Since Release


Atmospheric CO2 Concentration, in ppm
400
350
300
250
200
1000
1200
1400
1600
1800
2000
Year CE
Last Time CO2 of > 300 ppm: ≈ 300,000 Years Ago (Pre Homo Sapiens)
130 ppm ≈ 1,000 GtCO2

https://www.carbonbrief.org/analysis-global-fossil-fuel-emissions-up-zero-point-six-per-cent-in-2019-due-to-china



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 CO_2
- fortunately, no signs of net exhaustion *yet*
- unknown: could also ramp up (e.g., plants)

Long-Lived GHG Emissions

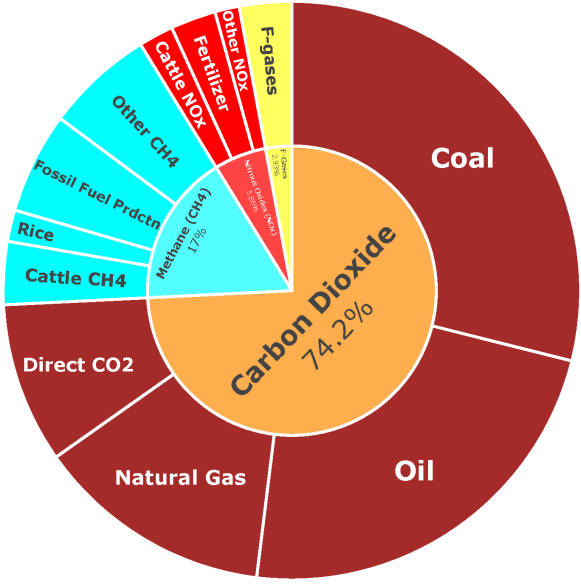
Highly correlated (many even from same sources):

- CO_2 (3/4 of GHG, longest-term).
- Methane CH_4 (1/8 of GHG).
  - Much more opaque to IR
  - immediate control has big short-term payoffs.
  - CH_4 decays to $\approx$ minute CO_2.
- Other (NOx, CFC).

Global Warming Potential (GWP)

- CH_4 warms more, but doesn't last as long.
- CO_2: GWP=1.
- **$GtCO_2e$**: measure of warming power
- We use standard GWP factors.

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


Coal
Oil
Natural Gas
Direct CO2
Cattle CH4
Rice
Fossil Fuel Prdctn
Other CH4
Cattle NOx
Fertilizer
Other NOx
F-gases
Carbon Dioxide
74.2%
Methane (CH4)
17%
Nitrous Oxide (N2O)
5.9%
F-Gases
2.9%

Land Charge

- (Human) land charge (per year) is reduced (forest) absorption of CO_2.
- 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

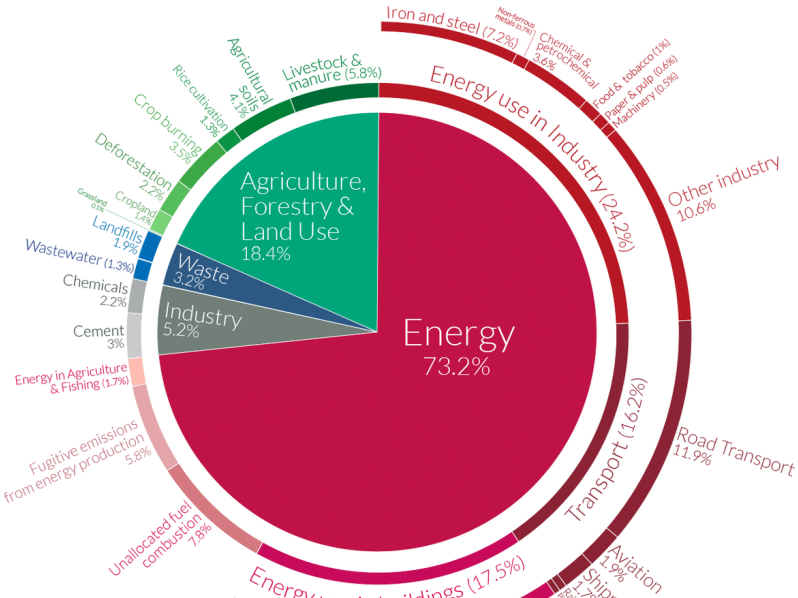
World $GtCO_2$ Fuel Emissions (Only CO_2)

From	$GtCO_2$
Coal	15
Oil	12
Gas	7
Other	5
Total	38

Methane And NOx: $GtCO_2$

From	$GtCO_2e$
Cattle	3
Fossil Fuel	3
Rice	1
Fertilizer	1
Total	12

Circle Plot


Agriculture, Forestry & Land Use 18.4%
Waste 3.2%
Industry 5.2%
Energy 73.2%
Livestock & manure (5.8%)
Agricultural soils 4.1%
Rice cultivation 1.3%
Crop burning 3.5%
Deforestation 2.2%
Croplands 1.4%
Grassland 0.1%
Landfills 1.9%
Wastewater (1.3%)
Chemicals 2.2%
Cement 3%
Energy in Agriculture & Fishing (1.7%)
Fugitive emissions from energy production 5.8%
Unallocated fuel combustion 7.8%
Energy use in Industry (24.2%)
Iron and steel (7.2%)
Non-ferrous metals (0.7%)
Chemical & petrochemical 3.6%
Food & tobacco (1%)
Paper & pulp (0.6%)
Machinery (0.5%)
Other industry 10.6%
Transport (16.2%)
Road Transport 11.9%
Aviation 1.9%
Energy

GHG Sources

From	$GtCO_2e$
All = Power, Heat, Agriculture	50
Agriculture	10
Non-Agriculture	40
Combustion	33
Cement	10
Airplanes	2

From	$GtCO_2e$
Transport	8
Electricity	14
Heating	4
Industrial	16

Electrifying

- Think 25-35 $GtCO_2e$ is easily electrifiable.
- Think 15-25 $GtCO_2e$ is not (ag, flying, etc.)

Summary

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