How do the people affect contemporary atmospheric CO_2?

Explaining and Predicting Fossil Fuel Emissions

Unlike physical and chemical systems, there are no equations to predict future human behavior and decision-making! Instead we approach the problem of quantifying drivers of fossil fuel emissions of CO_2 using a diagnostic approach that explains the past, and try to anticipate how these drivers might change in the future.

Since the 1990s, most economists and policy experts have used an approach developed by Japanese economist Shoichi Kaya. His idea is to apportion changes in emissions according to socio-economic changes, leading to the ***Kaya Identity***:

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E}$$

where

F is global CO_2 emissions from human sources,
P is global population,
G is world GDP (gross domestic product in dollars), and
E is global energy consumption.

In plain English, the Kaya Identity states that:

"fossil fuel ***emissions*** are equal to ***population*** (P), times ***dollars of economic activity per capita*** (G/P), times the amount of ***energy required to produce a dollar of economic activity*** (E/G), times the amount of ***fossil fuel required to produce a unit of energy*** (F/E)."

The Kaya Identity is actually kind of obvious if you think it through. You can see this if you work through the algebraic cancelation in the formula, which just leads to $F = F$!

A lot of people ***mistakenly believe that population growth is the driver of emissions growth. This is wrong: the people are already here!*** According to UN projections, global population (P) is only expected to grow by about 30% in the 21st Century, whereas the global economy (G) is expected to grow by 1600% (this is just 2.8% annual growth in *GDP*).

What's really driving the acceleration in emissions is that billions of people in the developing world are finally emerging from abject poverty, which is a good thing! We wouldn't hope for people to remain desperately poor, nor would we want massive human dieoffs. Since we don't want to reduce P or G/P in the Kaya Identity, our only realistic hope of reducing emissions is to ***improve the energy efficiency of the world economy (reduce E/G) and to drastically reduce the carbon required to produce energy (F/E).***

Carbon Arithmetic

When a ton of carbon is burned, 3.7 tons of CO_2 is produced because the mass of CO_2 also includes the mass of the oxygen which has been chemically bound to the carbon. Scientists prefer to work with tons of carbon rather than tons of CO_2, because it lets us use consistent units in the air, land, and oceans. Economists and policy analysis prefer to use tons of CO_2, which leads to no end of confusion. Just be careful to note which is which, and remember that ***1 ton of carbon equals 3.7 tons of*** CO_2***.***

Virtually everyone in the climate world uses metric tonnes (spelled the British way, go figure) rather than the smaller ones. **One metric tonne = 1000 kg = 2200 pounds**.

Because there's so much CO_2 in the world, we typically use the Latin prefix "giga," meaning billions, with both carbon and CO_2 units. ***One gigaton of Carbon = 1 billion tonnes = 10^9 tonnes = 10^{12} kg***. We abbreviate this unit as 1 GtC. Economists and policy wonks prefer $GtCO_2$, and exactly as we saw before 1 $GtCO_2$ = 3.7 GtC.

Fun fact! ***A gigaton is precisely the mass of 1 cubic kilometer of pure water***.

The ***global economy currently burns 10 GtC of fossil fuels each year*** (abbreviated 10 GtC/yr). This number is rising fast because of explosive economic growth in China. India is not far behind and subSaharan Africa's turn will come after that.

To find the change in concentration of atmospheric CO_2 in ppm for each GtC emitted, we divide the mass of carbon emitted by the mass of the atmosphere, and then account for the different molecular weights of Carbon (12 grams/mole) and dry air (29 grams/mole). It's not as complicated as it sounds.

By a happy coincidence, the numbers work out so that adding 1 GtC to the atmosphere raises the concentration of CO_2 by almost exactly 0.5 parts per million by volume (ppmv or just ppm)! Equivalently ***1 ppm of atmospheric*** CO_2 ***= 2 GtC***.

The CO_2 concentration of the atmosphere is currently just over 400 ppm, so by the quick rule of thumb above we can tell that there are ***800 GtC of CO_2 in the atmosphere***. Atmospheric CO_2 is currently rising by about 5 GtC/yr (about 2.5 ppm/yr), which is only half the rate of fossil fuel combutions! In the year 1800, the CO_2 concentration was about 280 ppm (560 GtC) and at the depths of the last Ice Age 18,000 years ago the CO_2 concentration was about 180 ppm (360 GtC).

How much could our descendants raise the CO_2 concentration if they went crazuy and burned every bit of fossil fuel? This depends on how much fossil fuel there is in the ground. The total is estimated to be at least 4000 GtC and perhaps as much as twice that. ***If people eventually extract and burn 5,000 GtC, atmospheric CO_2 would rise by about 2500 ppm over its current value***, minus the amount that can be very slowly sequestered in the deep ocean. This would be a very bad idea!