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GLOBAL CARBON PROJECT

Animation: The carbon budget for 1.5 °C. 15 December 2019

This brief document describes the assumptions and data I used to conceive the animation, "The carbon budget for 1.5 °C" for release with the Global Carbon Budget 2019. Please also credit the critical work of Alistair Fitter and Jerker Lokrantz of Future Earth for creating the video itself.

Goal: I wanted to visualize the atmosphere as a "bucket" that we are filling with greenhouse gas pollution. I also wanted to display both the speed with which the bucket is filling and the cumulative responsibility for fossil CO_2 emissions from different countries and regions (European Union, United States, China, India, and Rest of the World). Note the recent WMO report United in Science (September 2019, and that we in the Global Carbon Project contributed to) estimated that global average surface temperatures have already increased by 1.1 °C.

Cumulative Carbon Budget: The most difficult decision to make for the video was how to choose a single value for the cumulative CO_2 emissions associated with staying below a global average temperature threshold of 1.5 °C. Our new estimate of cumulative fossil and land-use-change CO_2 emissions from 1850 through 2018 is 1610 ± 73 Gt CO_2 for fossil emissions and 752 ± 220 Gt CO_2 for land-use change, for a total of ~2370 Gt CO_2 (Friedlingstein et al. 2019). The emissions estimates for 2019 are 36.8 ± 1.8 Gt for fossil CO_2 and 43.1 ± 3.2 Gt CO_2 for both fossil and land-use change.

In comparison, here is some relevant text using slightly different numbers from the IPCC Special Report of Global Warming of 1.5 °C:

> "By the end of 2017, anthropogenic CO_2 emissions since the pre-industrial period are estimated to have reduced the total carbon budget for 1.5°C by approximately 2200 ± 320 Gt CO_2 (*medium confidence*). The associated remaining budget is being depleted by current emissions of 42 ± 3 Gt CO_2 per year (*high confidence*). The choice of the measure of global temperature affects the estimated remaining carbon budget. Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 Gt CO_2 for a 50% probability of limiting warming to 1.5°C, and 420 Gt CO_2 for a 66% probability (*medium confidence*)."

Rogelj et al. (2019) provided an update on cumulative emissions, with the following text taken from the authors' blog post:

> "Putting all these factors together and taking into account emissions since 2011 then results in a remaining carbon budget from 2018 onwards of 580 Gt CO_2 for a 50% chance of keeping warming below 1.5C. This is less than 15 years of global emissions at current rates. So, what does that mean? This means that if we start reducing emissions steeply now and by the time we reach net-zero levels we have not emitted more than 580 Gt CO_2, our best scientific understanding tells us have we expect a one-in-two chance that warming would be kept to 1.5C. Moreover, if we want to be sure that this is also true until the end of the century, we'd have to aim to emit only 480 Gt CO_2 until we reach net-zero instead. This is under 12 years of current emissions."

A number of issues complicate the determination. The estimate of 480 Gt CO_2 remaining carbon budget by Rogelj et al. is for a 50% probability of staying below 1.5 °C. The IPCC estimate of 420 Gt CO_2 is for a 66% probability of staying below. Neither is for a 90% probability. Furthermore, other authors have highlighted the importance of tipping points such as the emissions associated with permafrost thaw (Gasser et al. 2018). Some authors have even suggested we are substantially closer to the 1.5 °C budget than previously thought, and may have already passed the 1.5 °C threshold, a statement that is possible but not widely held in the scientific community. Some other recent studies have suggested the opposite, that the remaining carbon budget may be larger the IPCC and Rogelj et al. (2019) estimates above.

Selecting any one number for the cumulative and remaining carbon budget is therefore arbitrary. The current GCP estimate for cumulative emissions through 2018 was ~2370 Gt CO_2. I selected a cumulative emissions total of 1800 Gt CO_2 for the fossil fuel term (~200 Gt CO_2 more than at the end of 2018) and ~775 Gt CO2 for land-use-change emissions, ~25 additional Gt CO_2. The cumulative budget total was therefore ~2575 Gt CO_2. The video animation is based on the fossil-fuel numbers through 2019, with the 9% "remaining carbon budget" number representing the proportion of the 2019 cumulative fossil fuel emissions and a total of 1800 Gt cumulative fossil CO_2.

Emissions data: I used the Global Carbon Project's Global Carbon Budget 2019 dataset for the data source, our annual release of CO_2 emissions that includes estimates for countries and regions listed above. I focused on fossil CO_2 emissions back to 1870 (see spreadsheet for the numbers).

Shortcomings: The biggest shortcoming in my opinion is the lack of error or uncertainty estimates visualized in the animation. I could not figure how to do that well (and its inclusion would have required a determination of what the actual range is). My desired visual was a simple bucket. I had to compromise on the data estimates chosen, the data used, and how explicitly (or not) to include emissions from land use and other greenhouse gases (CH_4 and N_2O).

Global Carbon Budget 2019: For the three papers we published as part of the Global Carbon Budget 2019 release, see:
Friedlingstein et al. (2019) Global Carbon Budget 2019. Earth System Science Data
Peters et al. (2019) Carbon dioxide emissions continue to grow amidst slowly emerging climate policies. Nature Climate Change
Jackson et al. (2019) Persistent fossil fuel growth threatens the Paris Agreement and planetary health. Environmental Research Letters

I hope the animation captured a defensible picture of the pace of emissions change and spurs action to reduce global greenhouse gas emissions.
Sincerely,

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