Carbon Dioxide's Residence Time in the Atmosphere 20 July, 2023

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Carbon dioxide emissions into the atmosphere accumulate over time, and the total cumulative anthropogenic emissions up to reaching net zero are a good indicator of the eventual temperature when warming stabilizes (though this also depends upon what happens to non-CO_2 emissions). Hence scientists and policymakers often evaluate the remaining carbon budget in terms of total cumulative emissions or the rate at which our emissions need to decrease to keep below a given warming level (e.g., a 50% cut by 2030).

Fortunately, for the last several decades only about half of the emitted anthropogenic carbon dioxide has remained in the atmosphere with the other half having been removed by vegetation, soils and the ocean (Canadell et al., 2021). This reflects a smaller fractional removal for very recent emissions and a greater removal for emissions that took place longer ago. Typically, half of a given year's anthropogenic emissions will be removed after about 30 years (Joos et al., 2013).

Hence when humanity reaches net zero carbon dioxide emissions, we will fortunately have to face less than half the cumulative anthropogenic emissions remaining in the atmosphere and driving warming, with the exact fraction depending upon the emissions trajectory up to the point of net zero. If we think about how long it takes to get the carbon dioxide "out of our system", then about half of the last year's anthropogenic carbon dioxide emissions before net zero will be gone in about 30 years. This provides a useful indication of the timescale for natural removal, though removal of the remaining anthropogenic carbon dioxide will take much, much longer than the removal of the first 50%.

While the carbon budget can be usefully divided among nations or sectors, atmospheric concentrations of carbon dioxide do not facilitate setting national targets the way emissions do and are instead valuable indicators of worldwide trends in sources and sinks. If we were to abruptly cease carbon dioxide emissions, roughly a quarter of the anthropogenic increase in atmospheric carbon dioxide concentrations would be removed by land and ocean uptake over the subsequent 30 years or so, though the decrease in concentrations in the real world would depend strongly on the path taken towards net zero (e.g., Jones et al., 2019).

References:

Canadell, J. G. et al. (2021). *Global Carbon and other Biogeochemical Cycles and Feedbacks. In: Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V. et al. (eds.)]. Cambridge University Press, NY and UK (see FAQ 5.1, for example).

Jones, C.D., Frölicher, T.L., Koven, C., MacDougall, A.H., Matthews, H.D., Zickfeld, K., Rogelj, J., Tokarska, K.B., Gillett, N.P., Ilyina, T. and Meinshausen, M. (2019). The Zero Emissions Commitment Model Intercomparison Project (ZECMIP) contribution to C4MIP: quantifying committed climate changes following zero carbon emissions. *Geoscientific Model Development*, *12*(10), 4375-4385.

Joos, F. et al. (2013). Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. *Atmospheric Chemistry and Physics*, *13*(5), 2793-2825 (see Fig. 1, for example).