# A Peek at Peaking: Exploring the Range of Climate Peaks

The Paris climate agreement calls for the world to reach net zero greenhouse gas (GHG) emissions by around 2050 to limit the worst effect of global warming. But today, annual GHG emissions are still rising. Our first big challenge is to halt that increase. Annual emissions must *peak* before they can start to fall.

Even after annual emissions peak, the world will keep warming. That's because GHGs will continue to build up in the atmosphere until we reach net zero emissions. Global temperatures won't peak until net zero and they might even rise for a little while longer due to lags in Earth's climate system. Climate change doesn't stop on a dime.

This infographic looks at the relationship between peaking emissions and peaking temperatures specifically for carbon dioxide ($CO_2$), the most important GHG.

The graphs below illustrate an optimistic scenario. More pessimistic scenarios would show higher peaks in later decades.

## Annual $CO_2$ emissions

Figure 1 shows worldwide annual $CO_2$ emissions from burning fossil fuels from 1850 to 2100 in billions of metric tonnes (Gt). The solid line from 1850 to 2022 shows actual emissions. The dashed line shows forecast emissions based a scenario called SSP1-2.6, one of many developed by the Intergovernmental Panel on Climate Change (IPCC). [1]

Under this optimistic scenario, annual $CO_2$ emissions are predicted to peak before 2030, drop to net zero around 2080, and then turn negative after that. Negative emissions would occur if we pull $CO_2$ out of the atmosphere using technologies like direct air carbon capture.

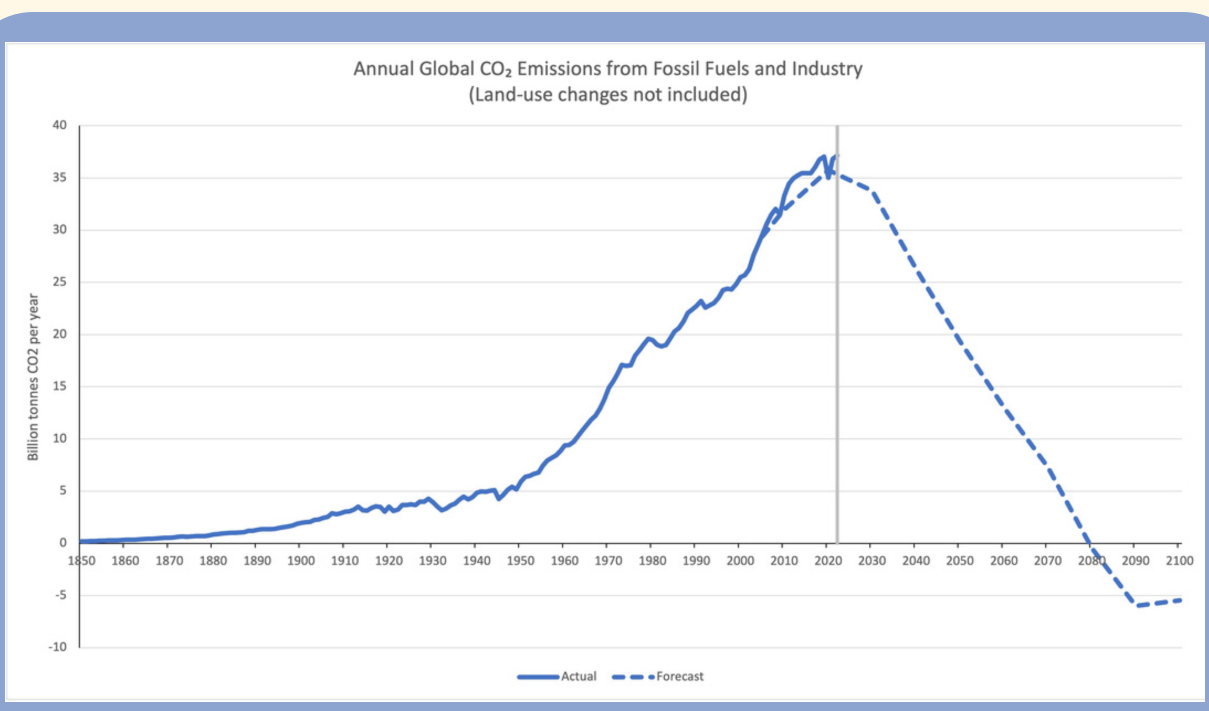


***Figure. 1**: Annual Global CO2 Emissions from Fossil Fuels and Industry. Actual values from Our World in Data [2]; forecast values based on IPCC scenario SSP1-2.6 (IMAGE model) from SSP Public Database (Version 2.0) [3], [4]*

## Atmospheric $CO_2$ concentration

Figure 2 shows atmospheric $CO_2$ concentration in parts per million (ppm) from 1850 to 2100.

Atmospheric concentration reflects the total amount of $CO_2$ built up in the atmosphere since pre-industrial times. Climate scientists use $CO_2$ concentration to help make temperature predictions because higher concentrations cause greater warming.

In the scenario shown here, $CO_2$ concentration won't peak until about 30 years after emissions peak.

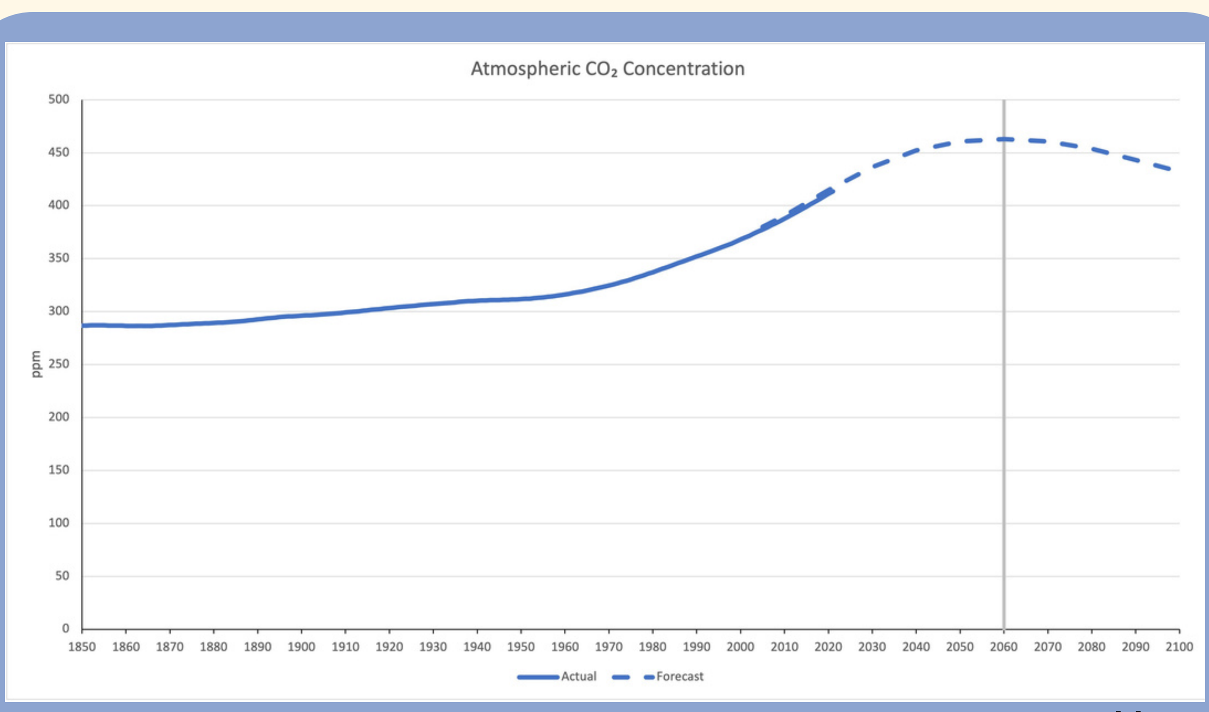


***Figure. 2**: Atmospheric $CO_2$ Concentration. Actual values based on Scripps $CO_2$ Program [5]; forecast values based on IPCC scenario SSP1-2.6 (IMAGE model) from SSP Public Database (Version 2.0) [3], [4]*

## Temperature

Figure 3 shows global average temperatures from 1850 to 2100 in °C relative to the commonly used pre-industrial baseline average from 1850-1900.

Historical temperatures from 1850 to 2023, shown as solid lines, come from several temperature models. They converge around 1980 when worldwide temperature data became more reliable.

The dashed line forecast shows temperatures peaking at about 1.8°C above the 1850-1900 baseline around 2075, several years after peak atmospheric $CO_2$ concentration.

Even under this optimistic scenario, it may take 40-50 years from peak emissions to peak warming.

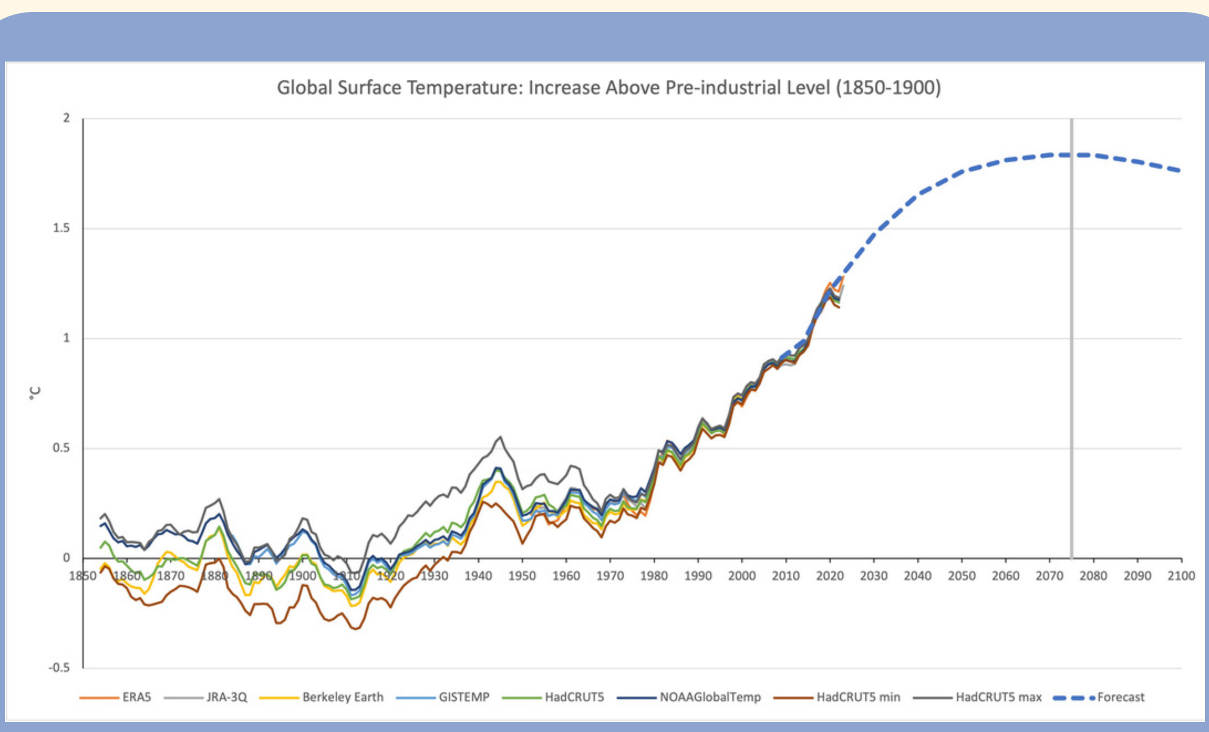


***Figure. 3**: Global Surface Temperature Increase Above Pre-Industrial Level (1850-1900). Actual values from EU Copernicus Climate Change Service report Global Climate Highlights 2023 [6]; forecast values based on IPCC scenario SSP1-2.6 (IMAGE model) from SSP Public Database (Version 2.0) [3], [4]*

## Notes

[1] Under IPCC SSP1-2.6, average global temperature "Stays below 2.0°C warming relative to 1850–1900 (median) with implied net zero $CO_2$ emissions in the second half of the century."

Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori, S.H. Faria, E. Hawkins, P. Hope, P. Huybrechts, M. Meinshausen, S.K. Mustafa, G.-K. Plattner, and A.-M. Tréguier, 2021: Framing, Context, and Methods. 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., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 147–286, doi:10.1017/9781009157896.003. p. 233.

[2] [Global Carbon Budget (2023) – with major processing by Our World in Data. "Annual $CO_2$ emissions" [dataset]. Global Carbon Project, "Global Carbon Budget" [original data]. Accessed Dec. 28, 2023.

[3] Keywan Riahi, Detlef P. van Vuuren, Elmar Kriegler, Jae Edmonds, Brian C. O'Neill, Shinichiro Fujimori, Nico Bauer, Katherine Calvin, Rob Dellink, Oliver Fricko, Wolfgang Lutz, Alexander Popp, Jesus Crespo Cuaresma, Samir KC, Marian Leimbach, Leiwen Jiang, Tom Kram, Shilpa Rao, Johannes Emmerling, Kristie Ebi, Tomoko Hasegawa, Petr Havlík, Florian Humpenöder, Lara Aleluia Da Silva, Steve Smith, Elke Stehfest, Valentina Bosetti, Jiyong Eom, David Gernaat, Toshihiko Masui, Joeri Rogelj, Jessica Strefler, Laurent Drouet, Volker Krey, Gunnar Luderer, Mathijs Harmsen, Kiyoshi Takahashi, Lavinia Baumstark, Jonathan C. Doelman, Mikiko Kainuma, Zbigniew Klimont, Giacomo Marangoni, Hermann Lotze-Campen, Michael Obersteiner, Andrzej Tabeau, Massimo Tavoni. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, Global Environmental Change, Volume 42, Pages 153-168, 2017, ISSN 0959-3780, DOI:10.1016/j.gloenvcha.2016.05.009

[4] Detlef P. van Vuuren, Elke Stehfest, David E.H.J. Gernaat, Jonathan C. Doelman, Maarten van den Berg, Mathijs Harmsen, Harmen Sytze de Boer, Lex F. Bouwman, Vassilis Daioglou, Oreane Y. Edelenbosch, Bastien Girod, Tom Kram, Luis Lassaletta, Paul L. Lucas, Hans van Meijl, Christoph Müller, Bas J. van Ruijven, Sietske van der Sluis, Andrzej Tabeau, Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm, Global Environmental Change, Volume 42, 2017, Pages 237-250, ISSN 0959-3780, DOI:10.1016/j.gloenvcha.2016.05.008. Data generated from SSP Public Database (Version 2.0) on Jan. 10, 2024.

[5] Spline of the atmospheric $CO_2$ record based on ice core data before 1959 and yearly averages of direct observations from Mauna Loa and the South Pole after and including 1959 (from Scripps $CO_2$ Program). Accessed Dec. 29, 2023.

Ice Core data from:
MacFarling Meure, C., D. Etheridge, C. Trudinger, P. Steele, R. Langenfelds, T. van Ommen, A. Smith, and J. Elkins. 2006. Law Dome $CO_2$, $CH_4$ and $N_2O$ Ice Core Records Extended to 2000 years BP. Geophysical Research Letters, 33(14), L14810. doi: 10.1029/2006GL026152

Scripps $CO_2$ Program Mauna Loa and South Pole data from:
C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, Exchanges of atmospheric $CO_2$ and $13CO_2$ with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001.

[6] Copernicus Climate Change Service (2023). "Global Climate Highlights 2023". Accessed Jan. 8, 2024.