

Addendum A: Climate-Related Deaths

Syncing the earlier CO₂ and mortality charts with *The Road to Net Zero* and *Net Zero Plus Carbon Removal* · October 2026

Overview

The two October briefings measure the climate problem in parts per million, degrees and dollars. This addendum measures it in lives. It revisits two earlier charts, one comparing CO₂ under a pledged 'net zero by 2050' with no reduction and one sketching climate-related deaths, and runs them through the same coupled carbon-cycle and climate model as the briefings. Four paths are now compared side by side: emissions held flat, the pledged net zero by 2050, the realistic net zero around 2074 from the first briefing, and net zero plus large-scale CO₂ removal from the second.

The four paths tell a sobering story. Human-caused warming already kills roughly 350,000 people a year (range about 220,000 to 575,000), counting only deaths from heat and temperature. About 15 million more will die between now and 2050 **on every path**, because the warming of the next 25 years is largely locked in by emissions already made and by the ocean's slow response. The paths only part ways after mid-century. By 2100 the toll reaches about 87 million if emissions stay flat, 66 million on the realistic net-zero path, 52 million if the 2050 pledge were kept, and 37 million with large-scale carbon removal.

The central lesson matches the briefings. Net zero stops the death toll from *rising*, but not the dying: with temperatures stuck near 2 °C, about 0.75 to 1 million people a year would still die from the added heat, year after year, into the next century. Only bringing temperatures back down, by taking carbon out of the air, brings the annual toll back toward today's level and below.

These are deliberately conservative numbers. They exclude deaths from floods, storms, crop failure, the spread of disease and conflict, and they leave out climate tipping points altogether. They should be read as a floor, and as a warning that argues for speed and early action rather than further delay.

Full-size versions of both figures follow these pages.

A1. One model, four paths

Four Paths, One Model: Emissions, CO₂ and Warming

Net CO₂ emissions, atmospheric CO₂ and warming above 1850–1900, 1959–2100. The three briefing paths plus the pledged 'net zero by 2050' path, run through the same coupled model.

CO₂ if nothing were absorbed, 2025

~564 ppm

vs 425 measured: oceans & land took ~56%

CO₂ peak, net zero by 2050

~449 ppm

~2043; realistic path ~483 ppm

Warming in 2100, net zero by 2050

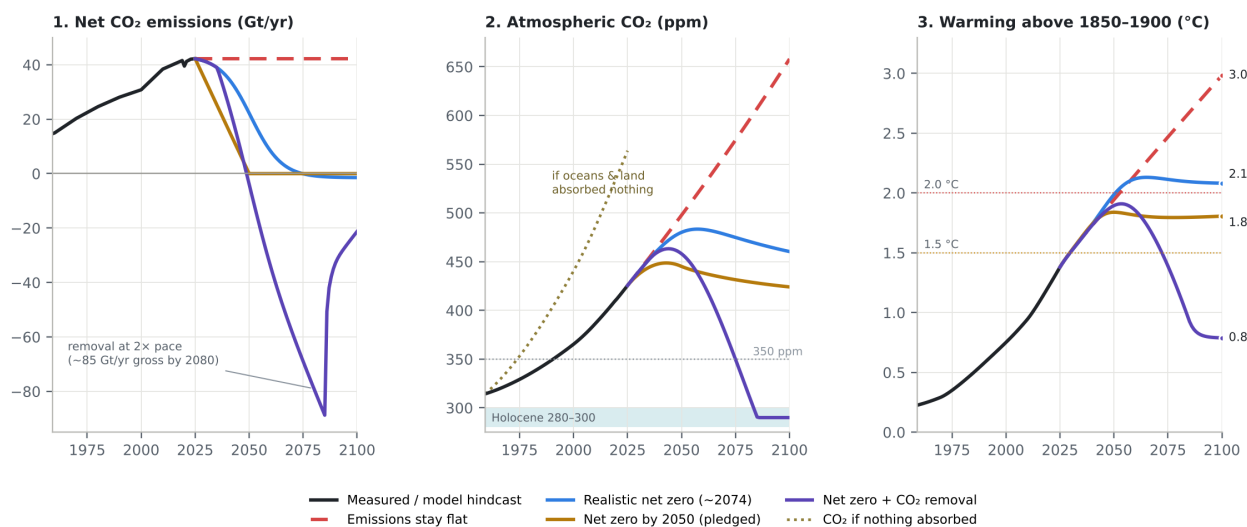
~1.8 °C

levels off; does not fall back

Warming in 2100, with CO₂ removal

~0.8 °C

the only path that cools



FairR-style carbon cycle (Joos et al. 2013; Millar et al. 2017) with sink weakening, two-layer energy-balance model (ECS 3 °C), calibrated to Mauna Loa CO₂ and 1.38 °C human-induced warming in 2025. Net zero by 2050 = linear decline of net emissions from 42.2 Gt (2025) to zero. Illustrative projection, not a forecast.

Figure A1 · Emissions, atmospheric CO₂ and warming, four paths (full size on page 5)

Figure A1 replaces the earlier 'Chart 1'. Its historical lines start from the same records (Scripps/NOAA Mauna Loa; Global Carbon Project), but every projection now comes from the coupled model used in the briefings, so the four paths can be compared directly.

What changed from the earlier chart

- **The 'if nothing were absorbed' line** now includes land-use emissions as well as fossil fuels. Had oceans and forests absorbed nothing since 1959, CO₂ would be about 564 ppm today instead of 425 ppm. Natural sinks have quietly removed about 56% of what we emitted.
- **Net zero by 2050 no longer flattens out at about 458 ppm.** In the coupled model CO₂ peaks near 449 ppm around 2043, then slowly falls to about 424 ppm by 2100 as the ocean keeps absorbing. Warming, however, peaks at about 1.8 °C and then stays there: the falling CO₂ and the deep ocean's delayed warming roughly cancel.
- **The realistic path is worse than the pledge.** Net zero around 2074 lets CO₂ climb to about 483 ppm and warming to about 2.1 °C, crossing 2 °C around 2051. Emissions held flat reach about 3.0 °C by 2100 and are still climbing.
- **Only removal reverses the curve.** Net zero plus removal at twice the pace of emission cuts brings CO₂ back to about 290 ppm by the mid-2080s and warming down to about 0.8 °C by 2100, matching the second briefing.

The model reproduces the briefings closely: peak CO₂ of about 483 ppm on the realistic path and 463 ppm with removal, warming of about 2.1 °C and 1.9 °C at the peaks, and the year-by-year removal table of the second briefing to within a few ppm and about 0.05 °C.

A2. Climate-attributable deaths

Climate-Attributable Deaths: Four Paths

Excess deaths from human-caused warming, 1959–2100 (temperature-related deaths only; central estimate, with low-high range from published studies).

Deaths per year today (2025)
~354,000
range 218,000–575,000

Deaths 2026–2050, every path
~15 million
range 9–24 M; largely locked in

Deaths 2026–2100, flat emissions
~87 million
range 53–141 M

Lives saved by CO₂ removal
~28 million
vs. realistic net zero; ~49 M vs. flat

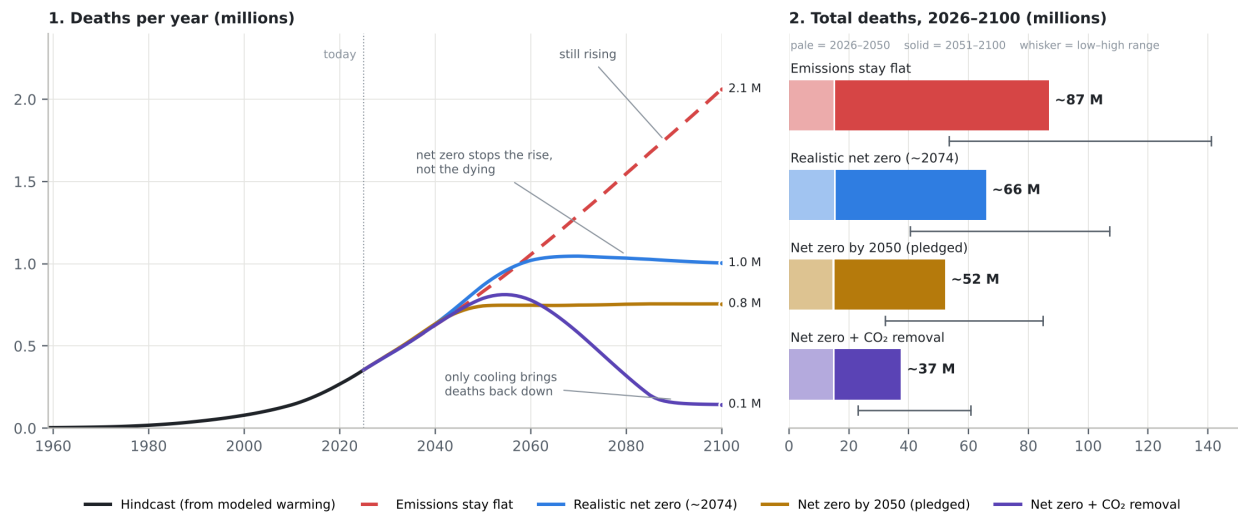


Figure A2 · Climate-attributable deaths, four paths (full size on page 6)

How the model is built

- **Deaths follow warming.** Each year's excess deaths equal world population times a mortality coefficient times the square of human-caused warming. The square reflects a well-established finding: each additional degree is deadlier than the last, because heat extremes rise faster than the average.
- **Two published anchors set the range.** The low coefficient reproduces Bressler (2021), who estimated about 83 million temperature-related deaths by 2100 on a path to about 4.1 °C. The high coefficient reproduces Carleton et al. (2022), who found warming of roughly 4.5 °C would add about 73 deaths per 100,000 people a year, as many as all infectious diseases kill today. The central line is the geometric mean of the two.
- **Today's toll checks out.** The model's 218,000–575,000 deaths a year in 2025 brackets the independent estimates: about 37% of heat deaths are attributable to human-caused warming (Vicedo-Cabrera et al., 2021), and the Lancet Countdown (2025) reports about 546,000 heat-related deaths a year, which implies roughly 200,000 caused by climate change.
- **Population** follows the UN's 2024 medium projection, peaking near 10.3 billion in the mid-2080s.

Results

Path	Deaths/yr 2050	Deaths/yr 2100	Total 2026–2050	Total 2026–2100 (range)
Emissions stay flat	0.83 M	2.06 M	15 M	87 M (53–141)
Realistic net zero (~2074)	0.87 M	1.00 M	15 M	66 M (41–107)
Net zero by 2050 (pledged)	0.74 M	0.76 M	15 M	52 M (32–85)
Net zero + CO ₂ removal	0.79 M	0.14 M	15 M	37 M (23–61)

Central estimates; ranges use the low and high coefficients. M = million.

Key insights

- **The next 25 years are already written.** Through 2050 the four paths kill almost exactly the same number of people, about 15 million. Warming lags emissions by a decade or more, and cutting fossil fuels also clears the cooling haze of air pollution, which briefly adds warmth. Choices made now are paid for, or spared, by our children and grandchildren.
- **Delay is counted in lives.** Slipping from the 2050 pledge to the realistic 2074 path costs about 14 million additional lives by 2100. Doing nothing costs about 35 million more than the pledge.
- **Net zero is a plateau, not a recovery.** On both net-zero paths, annual deaths level off at two to three times today's toll and stay there, because temperatures do not fall on their own.
- **Cooling is what saves lives at scale.** Large-scale removal saves about 28 million lives compared with the realistic path and about 49 million compared with flat emissions. By 2100 it brings annual deaths to about 140,000, well below today's level.
- **The burden falls on those least responsible.** Both source studies find most deaths occur in hot, lower-income regions of Africa, South Asia and the Middle East, while some cold, wealthy regions see small net gains.

Read these numbers as a floor

Every scenario here, and in both briefings, sits at the low end of the plausible risk, for two reasons:

- **Most causes of climate death are left out.** The source studies count only deaths from heat and temperature. Deaths from floods, storms, wildfire smoke, crop failure and hunger, the spread of malaria and other diseases, displacement and conflict are not included.
- **Tipping points are not modeled.** Ice-sheet collapse, abrupt permafrost thaw, Amazon dieback and a shutdown of the Atlantic overturning circulation (AMOC) are excluded. Their precise timing is debated, which is exactly why they cannot be placed on a curve, but each would push warming, sea level or regional disruption beyond anything shown.

The right response to that uncertainty is not to wait for better numbers. It is to act faster and earlier than any of these paths assume: every year of delay adds deaths that no later action can undo.

Other caveats

- The mortality coefficient is held fixed. Richer, better-adapted societies may cope better; poorer, hotter ones may not.
- The two source studies differ by a factor of about 2.6, which is the main reason for the wide ranges.
- Deaths are counted against a world without human-caused warming. All results are illustrative models built from published sources, not forecasts.

Looking ahead: Addendum B

A second addendum will test extraordinary cooling interventions aimed at the frozen parts of the planet: refreezing and restoring Arctic sea ice, halting Greenland ice-sheet melt, and stabilizing the Antarctic ice sheets now sliding into the Southern Ocean. The death model here is driven by global temperature, so any extra cooling those measures deliver can be run through it directly. Their larger payoff, though, lies in the risks this addendum leaves out: sea-level rise and the tipping points above. Addendum B will need to add those channels.

Sources

Bressler, R. D., "The mortality cost of carbon," *Nature Communications* (2021). Carleton, T. et al., "Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits," *Quarterly Journal of Economics* (2022). Vicedo-Cabrera, A. M. et al., "The burden of heat-related mortality attributable to recent human-induced climate change," *Nature Climate Change* (2021). Romanello, M. et al., *The 2025 report of the Lancet Countdown on health and climate change*, The Lancet (2025). World Health Organization, *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s* (2014). United Nations, *World Population Prospects 2024*. Global Carbon Project, *Global Carbon Budget 2025*. Scripps Institution of Oceanography and NOAA, Mauna Loa CO₂ record. Joos, F. et al. (2013) and Millar, R. et al. (2017), *Atmos. Chem. Phys.* Geoffroy, O. et al., *J. Climate* (2013). Forster, P. et al., "Indicators of Global Climate Change 2025," *Earth Syst. Sci. Data* (2026). Companion briefings: *The Road to Net Zero and Net Zero Plus Carbon Removal* (October 2026). All projections are illustrative models built from these sources, not forecasts.

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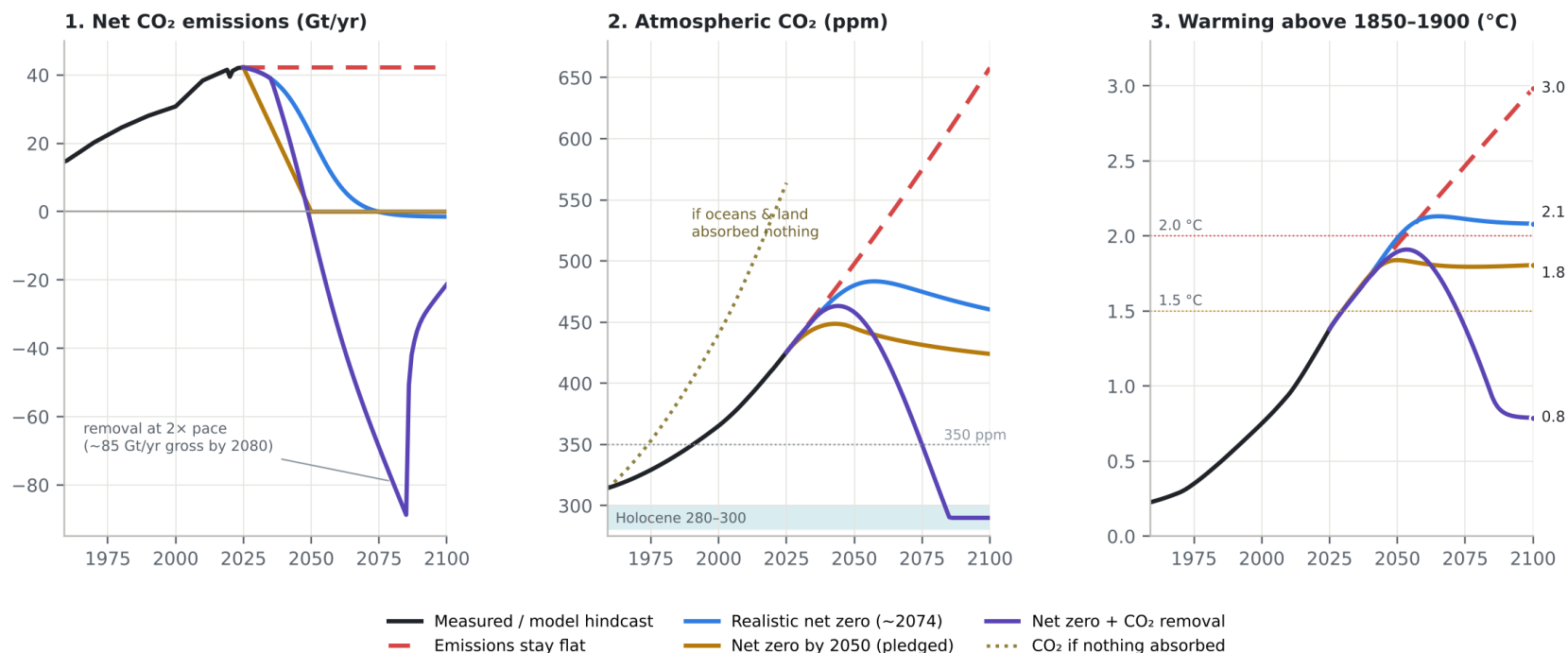
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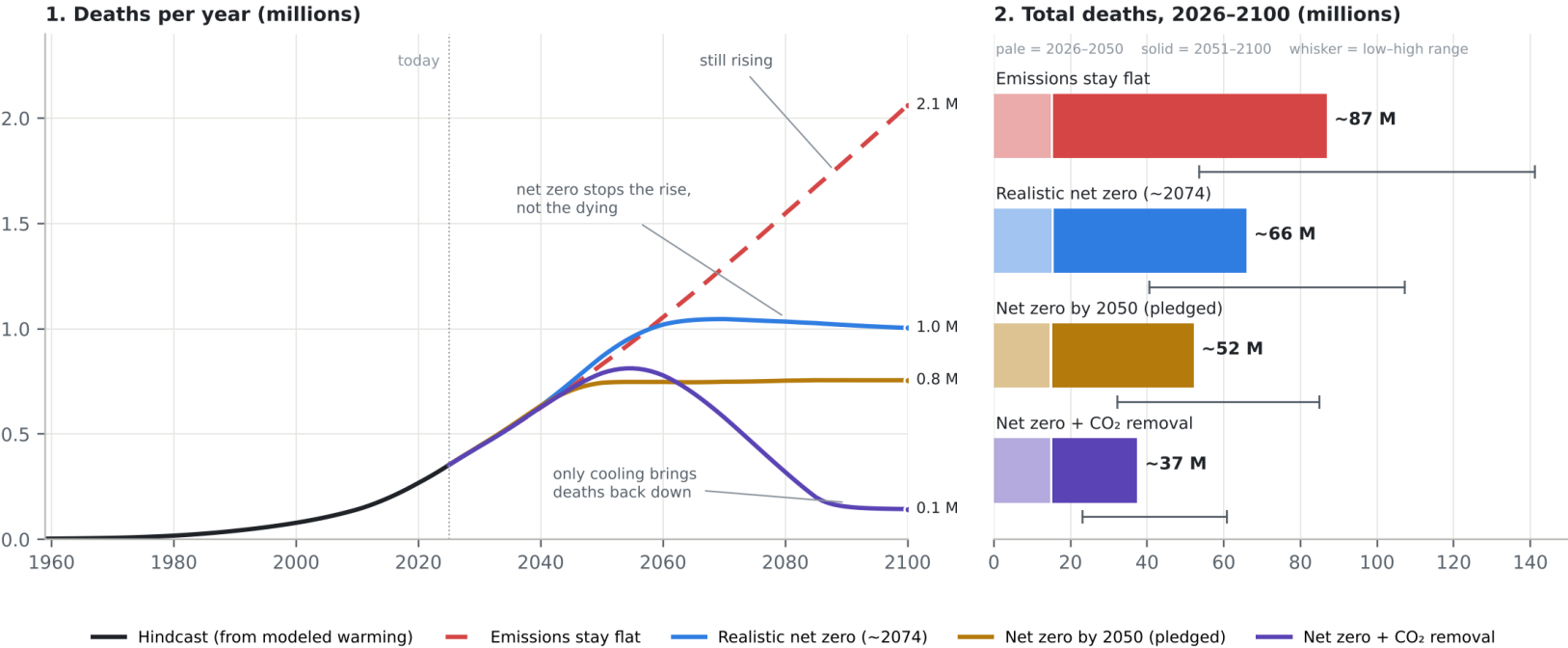
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Deaths = population (UN WPP 2024) × k × warming². Low k fitted to Bressler (2021): 83 M deaths by 2100 at ~4.1 °C; high k fitted to Carleton et al. (2022): +73 per 100,000 at ~4.5 °C; central = geometric mean. Temperature-related mortality only: excludes floods, storms, crop failure, disease spread, conflict and tipping points, so these are low-end estimates. Illustrative, not a forecast.