

The Road to Net Zero

Timeline, costs and benefits, atmospheric CO₂, global temperature and economic effects · October 2026

Overview

This briefing brings together five linked views of the global energy transition. Figure 1 sets out when key decarbonization milestones are realistically likely to be reached. Figure 2 estimates what the transition costs and saves, year by year and in total. Figure 3 shows how global CO₂ emissions could fall to net zero and what that means for the concentration of CO₂ in the atmosphere, as tracked by the Keeling curve. Figure 4 translates the CO₂ path into global mean surface temperature, including other greenhouse gases, aerosol pollution, Earth-system feedbacks and a moderate carbon-removal option. Figure 5 traces the knock-on effects for GDP, inflation, household income and other economic indicators.

The five views tell a consistent story. The power sector moves first, the hardest sectors move last, and true global net zero lands somewhere around 2065–2080. The transition costs more upfront for two decades or so and then pays back through lower fuel bills. Atmospheric CO₂ keeps rising until about the 2050s, peaks well before net zero, and then slowly declines. The 1.5°C target is almost certainly missed; 2°C remains possible with urgent action. Warming crosses 1.5°C around 2030, peaks near 2.1°C around 2070, and then levels off rather than falling. Economically, the transition is a modest drag in the 2030s and a clear gain from the 2040s onward, with fossil-fuel exporters bearing the heaviest costs.

Full-size versions of each figure follow these pages.

1. Realistic timeline to net zero

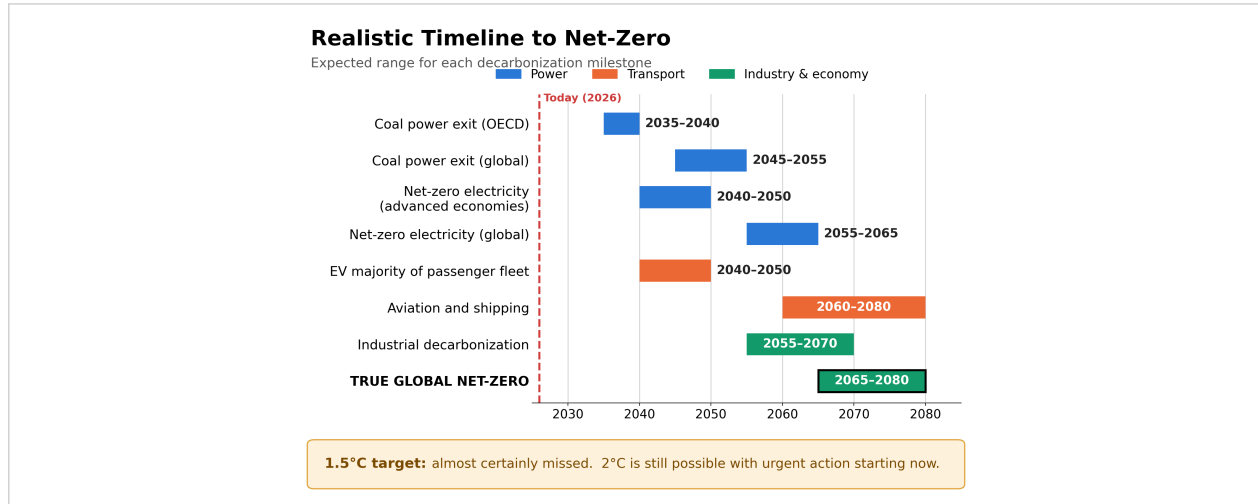


Figure 1 · Realistic timeline to net zero (full size on page 10)

Milestone	Realistic range
Coal power exit (OECD)	2035–2040
Coal power exit (global)	2045–2055
EV majority of passenger fleet	2040–2050
Net-zero electricity (advanced economies)	2040–2050
Net-zero electricity (global)	2055–2065
Industrial decarbonization	2055–2070
Aviation and shipping	2060–2080
True global net zero	2065–2080
1.5°C target	Almost certainly missed; 2°C possible with urgent action

The pattern is clear. The power sector goes first, with advanced economies leading the rest of the world by about 10–15 years. The hardest sectors, aviation, shipping and heavy industry, have the widest and latest ranges, and those sectors are what push true global net zero out to 2065–2080.

2. Global cost versus benefit

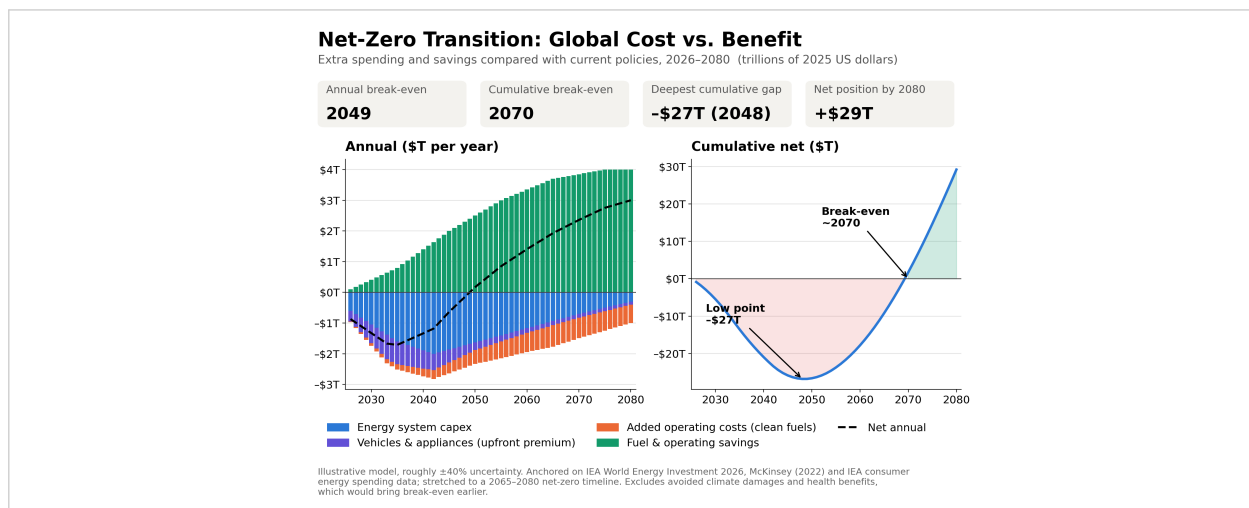


Figure 2 · Net-zero transition cost vs. benefit (full size on page 11)

No one keeps an audited global ledger of transition costs, so Figure 2 is a transparent model rather than a forecast. It counts only the *extra* spending and savings compared with sticking to current policies, in 2025 US dollars, and stretches published estimates to match the 2065–2080 net-zero timeline.

Anchor figures

- Global energy investment is expected to reach about \$3.4 trillion in 2026, with about \$2.2 trillion going to clean energy, almost double fossil fuel investment (IEA, World Energy Investment 2026).
- For a full 2050 net-zero transition, McKinsey estimated about \$275 trillion of spending on energy and land-use assets, or \$9.2 trillion a year on average, roughly \$3.5 trillion a year more than current spending.
- Consumers worldwide spent around \$10 trillion on energy in 2022, more than \$1,200 per person. About half went to oil products and another third to electricity (IEA).

How the model is built

- **Energy system capex** (power, grids, storage, industry, hydrogen) peaks at about \$2 trillion a year of extra spending in the early 2040s. That is below McKinsey's \$3.5 trillion because this timeline is slower than their 2050 path.
- **Vehicles and appliances** is the extra upfront price of EVs, heat pumps and insulation compared with fossil equivalents. It peaks in the early 2030s and shrinks as EVs reach price parity. Heat pumps keep a small premium; the UK Climate Change Committee expects them to remain more expensive than gas boilers even in 2050.
- **Added operating costs** mainly reflect pricier clean fuels for aviation, shipping and heavy industry, such as green hydrogen and sustainable jet fuel.

- **Savings** come from avoided oil, gas and coal, minus extra electricity bills. They reach roughly 40% of today's consumer energy spending, consistent with IEA analysis that a net-zero path more than halves the energy system's operating costs within a decade, but spread over a slower timeline.

Key results

The result is a J-curve. Annual savings overtake annual costs around 2049. The cumulative gap bottoms out at roughly –\$27 trillion in 2048, breaks even around 2070, and reaches about +\$29 trillion by 2080.

Caveats

- Treat every line as roughly $\pm 40\%$. Fuel prices alone can move the break-even dates by a decade or more.
- The direction is well supported. A peer-reviewed Oxford study (Way et al., Joule, 2022) found a fast transition by around 2050 would save at least \$12 trillion compared with continuing current fossil fuel use.
- Global totals hide who pays and who saves. In emerging markets, rising electricity use and appliance ownership could push household energy bills higher, while advanced economies see bills fall.
- The model excludes avoided climate damages and air-pollution health costs. Both would bring break-even earlier, likely by a lot.

3. CO₂ emissions and the Keeling curve

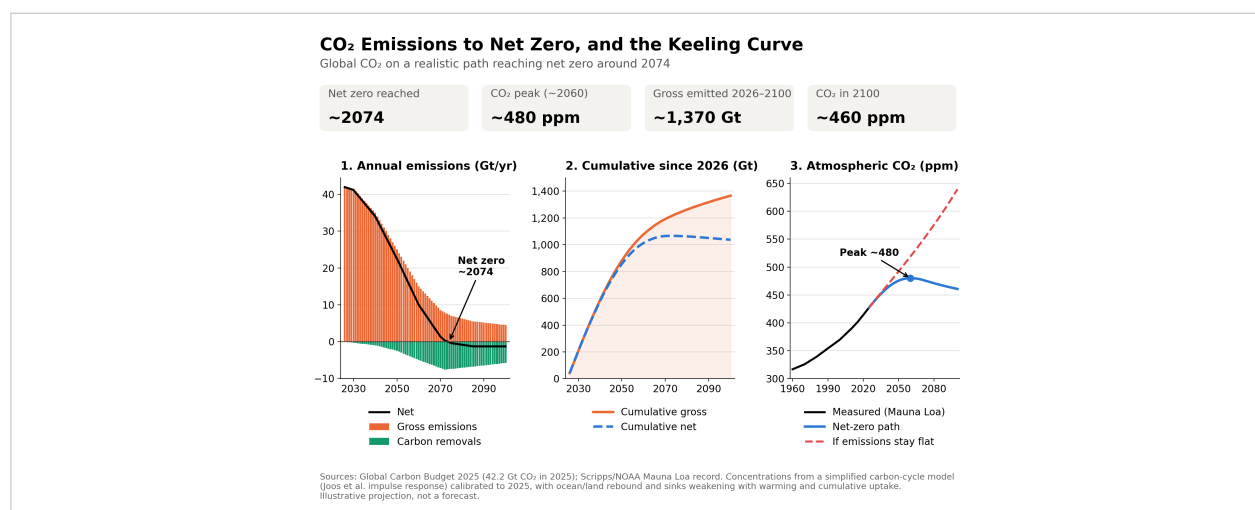


Figure 3 · CO₂ emissions to net zero and the Keeling curve (full size on page 12)

Figure 3 starts from the latest measured data. Fossil fuels and net land-use change produced about 42.2 billion tonnes of CO₂ in 2025 (Global Carbon Budget 2025). CO₂ at Mauna Loa reached 432 ppm in May 2026, 1.8 ppm above May 2025 (Scripps/NOAA). The

emissions path follows the Figure 1 timeline and reaches net zero around 2074.

Key insight: CO₂ peaks before net zero

Atmospheric CO₂ peaks at about 480 ppm around 2060, more than a decade before net zero. CO₂ stops rising once emissions fall to about what the oceans and forests absorb each year. After net zero, natural sinks keep slowly drawing CO₂ down, so concentrations drift back toward about 460 ppm by 2100. If emissions instead stayed flat at today's level, CO₂ would reach about 640 ppm by 2100.

How the model is built

- **Emissions path.** Gross emissions start at 42 Gt and fall slowly at first, then steeply in the 2040s–60s as power, cars and industry decarbonize. A residual of about 5–7 Gt a year remains from aviation, shipping, cement and agriculture.
- **Removals.** Reaching net zero requires carbon removal (direct air capture, reforestation, bioenergy with carbon capture) to scale to about 7 Gt a year by the 2070s. That industry is tiny and unproven today, which makes it the weakest link in this path.
- **Keeling curve.** Concentrations come from a standard simplified carbon-cycle model (the Joos et al. impulse response), calibrated to match 2025 observations. Ocean and land sinks weaken as the world warms and as they absorb more carbon, and recover as warming eases; climate impacts on sinks already account for about 8% of the rise in CO₂ since 1960. The sink weakening is calibrated to match the coupled FaIR-style model in the companion briefing *Net Zero Plus Carbon Removal*, so both briefings show the same net-zero path.

Putting it in context

Net emissions of roughly 1,065 Gt before net zero compare with a remaining 1.5°C carbon budget of only about 170 Gt, about four years at 2025 emissions. That matches the Figure 1 verdict: 1.5°C missed, with peak warming likely in the 2°C range.

4. Global temperature

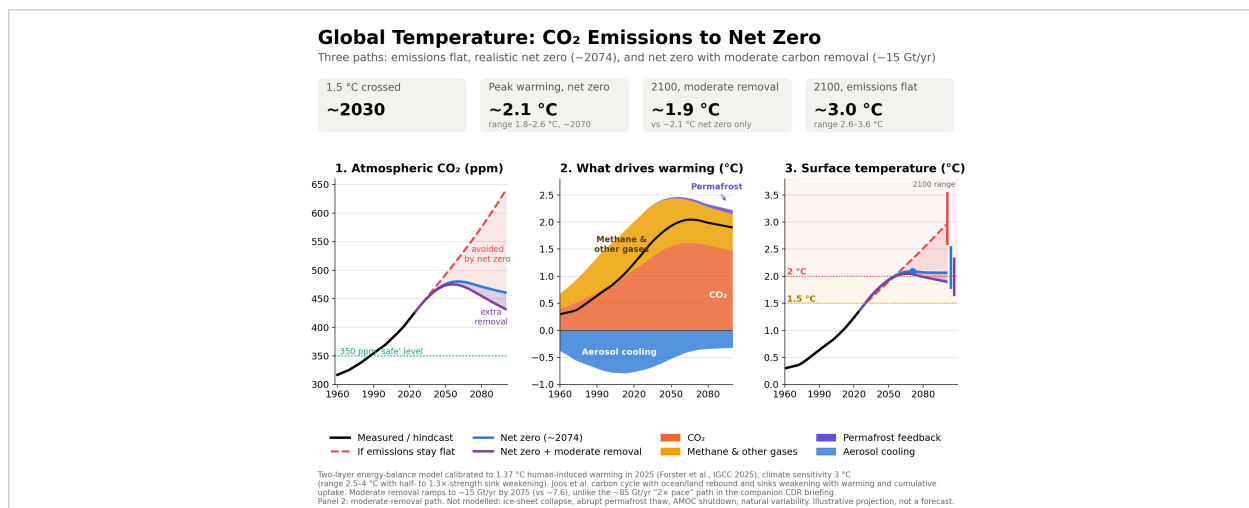


Figure 4 · Global temperature: CO₂ emissions to net zero (full size on page 13)

Figure 4 converts the CO₂ path from Figure 3 into global mean surface temperature (GMST). It compares three paths: emissions held flat at today's level, the realistic net-zero path reaching net zero around 2074, and the same path with a moderate increase in carbon removal.

How the model is built

- **Climate model.** A two-layer energy-balance model, the kind the IPCC uses to emulate full Earth-system models, with a fast surface layer and a slow deep ocean. It is calibrated to the latest measurements: human-induced warming reached 1.37°C above 1850–1900 in 2025 (Forster et al., Indicators of Global Climate Change 2025).
- **Climate sensitivity.** The central case assumes 3°C of eventual warming per doubling of CO₂, with a range of 2.5–4°C (IPCC AR6 “likely” range). For each sensitivity, the strength of aerosol cooling is set so the model reproduces observed warming to date, which is why higher sensitivities also unmask more warming later.
- **Feedbacks.** Fast feedbacks (water vapor, clouds, melting ice and snow) are built into the climate sensitivity. Weakening ocean and land carbon sinks are included in the CO₂ model, at half strength in the low case and 1.3× strength in the high case. Permafrost thaw is added as an explicit extra source, contributing under 0.1°C by 2100 on the net-zero paths.
- **Moderate carbon removal.** Removal ramps to about 15 Gt CO₂ a year by 2075, double the roughly 7.6 Gt in the base net-zero path, bringing net zero forward to about 2065 and making net emissions about –10 Gt a year by 2100. This is a different, much smaller program than the “2× pace” scenario in the companion briefing, where removal capacity grows by about 1.9 Gt every year and reaches about 85 Gt a year by 2080.

Reading the panels

- **Atmospheric CO₂ (panel 1).** The red shading shows CO₂ avoided by reaching net zero; the purple shading shows the extra drawdown from faster removal, which brings concentrations to about 430 ppm by 2100 versus about 460 ppm without it. Both remain well above the 350 ppm level often cited as a long-term safe target.
- **What drives warming (panel 2).** CO₂ (orange) is the dominant driver and stops growing once net zero is reached. Methane and other gases (amber) decline as fossil-fuel production winds down, though agriculture keeps some in place. Aerosol cooling (blue) has been masking roughly 0.75°C of warming; it fades as coal and oil are phased out, partly offsetting the methane cuts and keeping warming rising into the 2060s. Permafrost (violet) adds a thin but growing layer.
- **Surface temperature (panel 3).** Warming crosses 1.5°C around 2030, passes 2°C in the mid-2050s and peaks near 2.1°C (range 1.8–2.6°C) around 2070 on the net-zero path. It then levels off rather than falling: CO₂ declines, but the deep ocean is still catching up with past warming, and the two roughly cancel. With moderate removal, warming eases to about 1.9°C by 2100. If emissions stayed flat, warming would reach about 3.0°C (2.6–3.6°C) by 2100. Until about 2055 the flat path is briefly no warmer than net zero, because phasing out fossil fuels also removes their cooling aerosol haze. The bars at the right edge show each path's 2100 range across climate sensitivities.

Why carbon removal does less than you might expect

Moderate removal, about 370 Gt of extra removal by 2100, cools the planet by only about 0.15°C (range 0.13–0.22°C) by 2100. Two physical effects limit it. First, as CO₂ is pulled out of the air, oceans and land release some of their stored carbon back: here roughly 40% of the extra removal is offset by this rebound, close to the 46% found in the companion briefing. Second, the deep ocean releases stored heat slowly, so surface temperatures lag CO₂ by about a decade. Much larger cooling is physically possible but needs removal on an enormous scale: the companion briefing's "2× pace" scenario, reaching about 85 Gt a year by 2080 (about twice today's total emissions), returns CO₂ to about 290 ppm by the mid-2080s and warming to about 0.8°C by 2100. Running that removal schedule through this briefing's model gives nearly the same result. Carbon removal can lower temperatures, but the cooling scales with the tonnage, and the tonnage needed for large cooling is far beyond any IPCC pathway.

Caveats

- The 1.8–2.6°C peak range reflects climate sensitivity and the strength of sink weakening. Year-to-year natural variability adds about ±0.2°C, so individual years will cross 2°C before the long-term average does.
- The model excludes tipping points such as ice-sheet collapse, abrupt permafrost thaw, Amazon dieback and a shutdown of the Atlantic ocean circulation (AMOC), any of which

could add warming or regional disruption beyond the ranges shown.

- The remaining 1.5°C carbon budget from the start of 2026 is about 130 Gt CO₂, a little over three years of current emissions, which is why the curves cross 1.5°C around 2030.

5. Economic effects

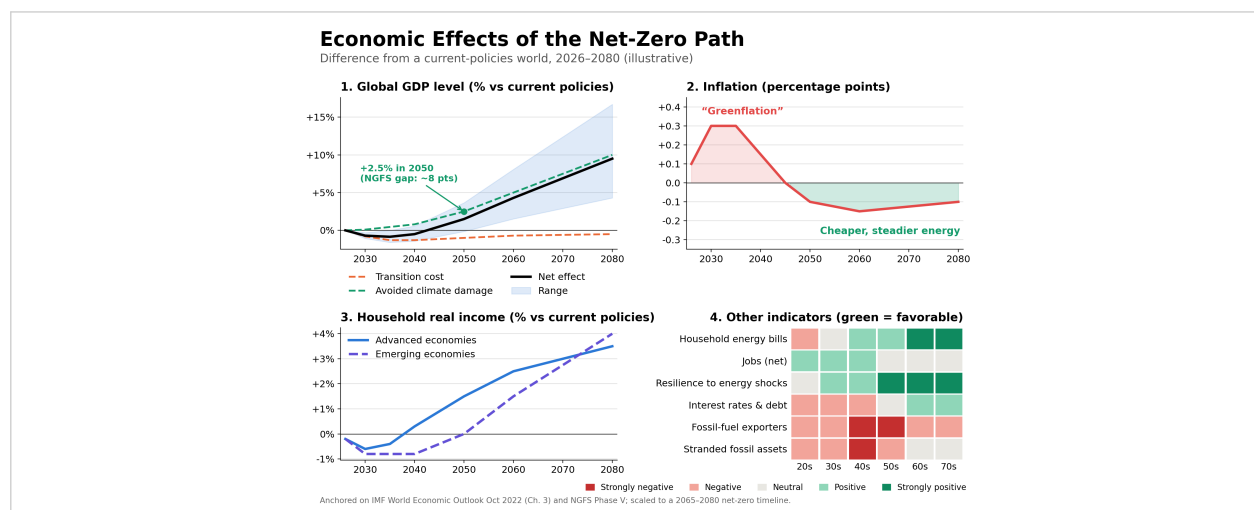


Figure 5 · Economic effects of the net-zero path (full size on page 14)

Figure 5 traces how the transition could affect the wider economy. Every line shows the difference from a current-policies world, not absolute levels, so a reading of +2% means 2% better than the economy would otherwise be. Like the other figures, these are directional curves built from published macro modelling, not forecasts.

Anchor figures

- The IMF (World Economic Outlook, October 2022, Chapter 3) estimated that a credible transition policy package could slow global growth by 0.15–0.25 percentage points a year until 2030 and raise inflation by 0.1–0.4 points. The growth cost is smaller for China, the US and the EU (0.05–0.20 points) and larger for fossil-fuel exporters and energy-intensive emerging economies.
- The Network for Greening the Financial System (NGFS, Phase V, 2024) estimated global GDP losses from climate damage by 2050 of about 15% under current policies versus about 7% under a net-zero-by-2050 path, a gap of roughly 8 percentage points.

Reading the panels

- **GDP (panel 1).** The transition cost (orange) is a drag of about 1% through the 2030s. Avoided climate damage (green) grows over time, and the net effect (black) turns positive in the early 2040s. The avoided-damage line sits at about +2.5% in 2050, well below the 8-point NGFS gap, for two reasons: this path reaches net zero around 2074 rather than 2050, so it avoids less warming by mid-century; and NGFS has since issued a notice to readers about the academic study behind its higher damage estimates. The shaded band shows the plausible range, with the upside reflecting the NGFS figures.
- **Inflation (panel 2).** Mild “greenflation” of up to about 0.3 points in the 2030s comes from carbon pricing and heavy investment demand. It fades by the mid-2040s and is followed by slight disinflation as cheap renewables replace volatile fossil fuels. True deflation is not expected, because central banks would offset it.
- **Household income (panel 3).** Advanced-economy households come out ahead first, from the late 2030s, as energy bill savings build. Emerging-economy households wait until around 2050, because rising electricity use and appliance ownership offset savings at first, but gain more later because they suffer more from climate damage.
- **Other indicators (panel 4).** Green cells are favorable for the economy and red cells unfavorable. Resilience to energy shocks improves steadily, which matters because oil-price spikes have historically triggered many recessions. Higher investment demand puts upward pressure on interest rates and public debt early on. Fossil-fuel exporters and owners of stranded fossil assets face their hardest decades in the 2040s and 2050s.

Caveats

- Timing and credibility matter. The IMF warns that delay makes the transition costlier, bringing slower growth and higher inflation; a late, disorderly transition would deepen the early dip.
- Avoided climate damage is the most uncertain element in this figure, which is why the GDP range is wide and widens over time.

Sources

International Energy Agency, *World Energy Investment 2026*; IEA, *Strategies for Affordable and Fair Clean Energy Transitions* (2024). McKinsey Global Institute, *The Net-Zero Transition* (2022). Way, R. et al., “Empirically grounded technology forecasts and the energy transition,” *Joule* (2022). UK Climate Change Committee, via Resolution Foundation analysis. Global Carbon Project, *Global Carbon Budget 2025*. Scripps Institution of Oceanography and NOAA Global Monitoring Laboratory, Mauna Loa CO₂ record. Joos, F. et al., carbon dioxide impulse response functions, *Atmos. Chem. Phys.* (2013). International Monetary Fund, *World Economic Outlook*, October 2022, Chapter 3. Network for Greening the Financial System, *NGFS Climate Scenarios Phase V* (2024). Forster, P. et al., “Indicators of Global Climate Change 2025,” *Earth System Science Data* (2026). IPCC, *Sixth Assessment Report*, Working Group I (2021). Millar, R. et al., FaIR simple climate model, *Atmos. Chem. Phys.* (2017). Companion briefing: *Net Zero Plus Carbon Removal* (October 2026). All projections are illustrative models built from these sources, not forecasts.

Realistic Timeline to Net-Zero

Expected range for each decarbonization milestone



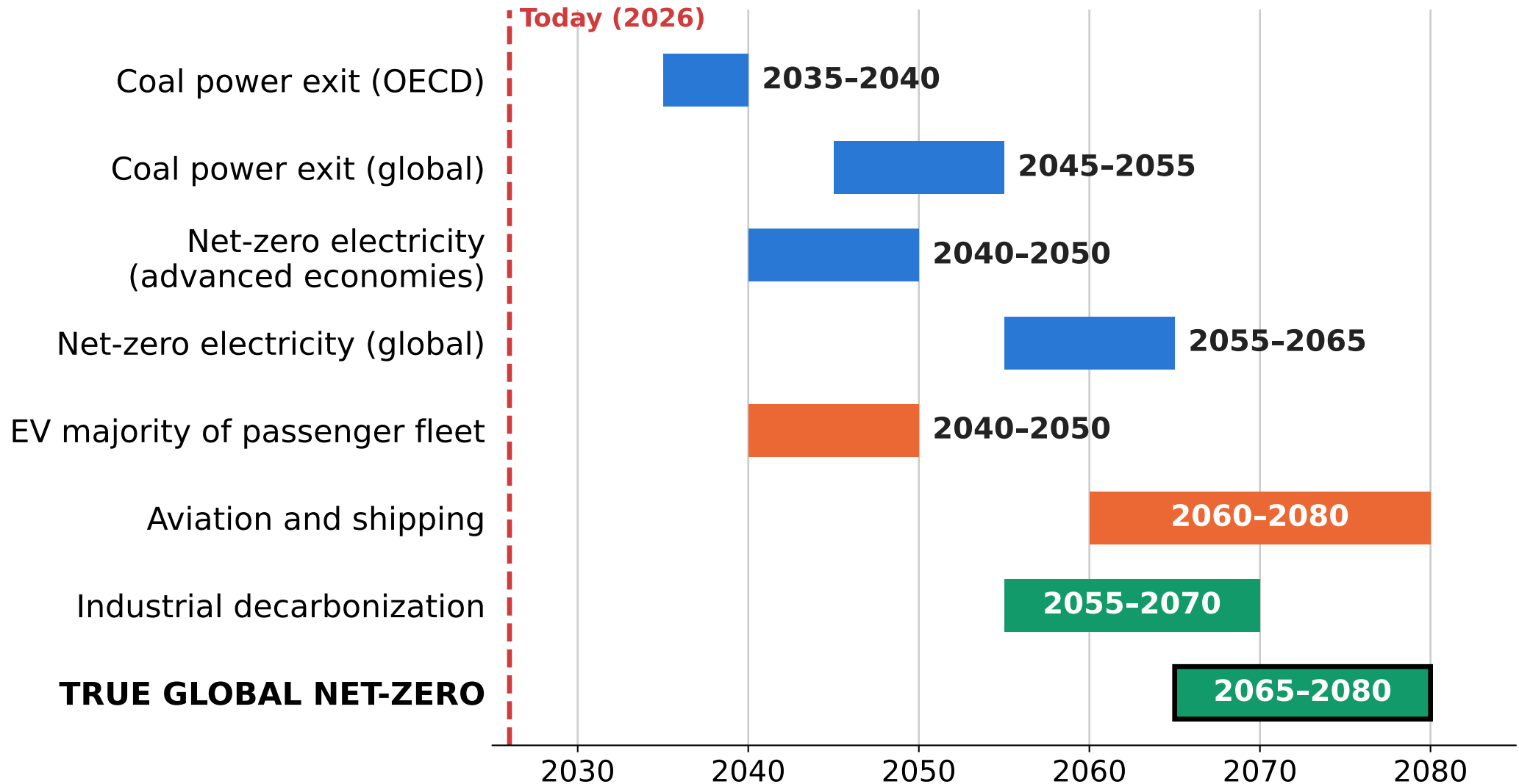
Power



Transport



Industry & economy



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1.5°C target: almost certainly missed. 2°C is still possible with urgent action starting now.

Net-Zero Transition: Global Cost vs. Benefit

Extra spending and savings compared with current policies, 2026–2080 (trillions of 2025 US dollars)

Annual break-even

2049

Cumulative break-even

2070

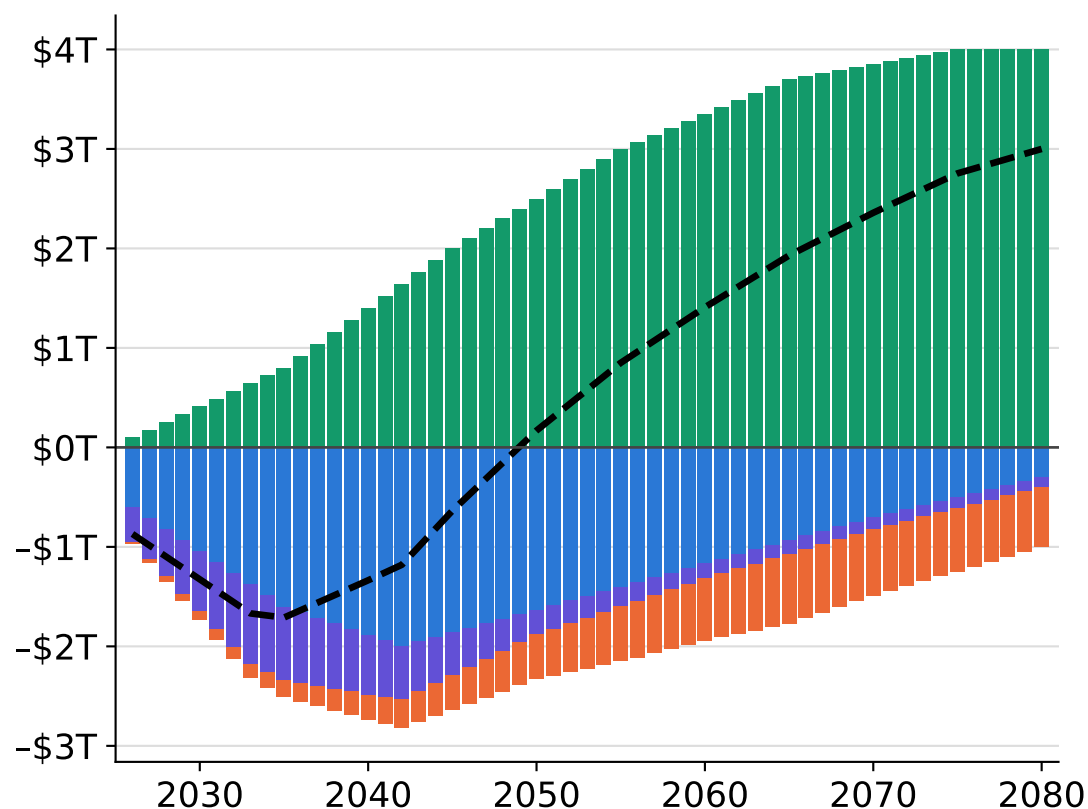
Deepest cumulative gap

-\$27T (2048)

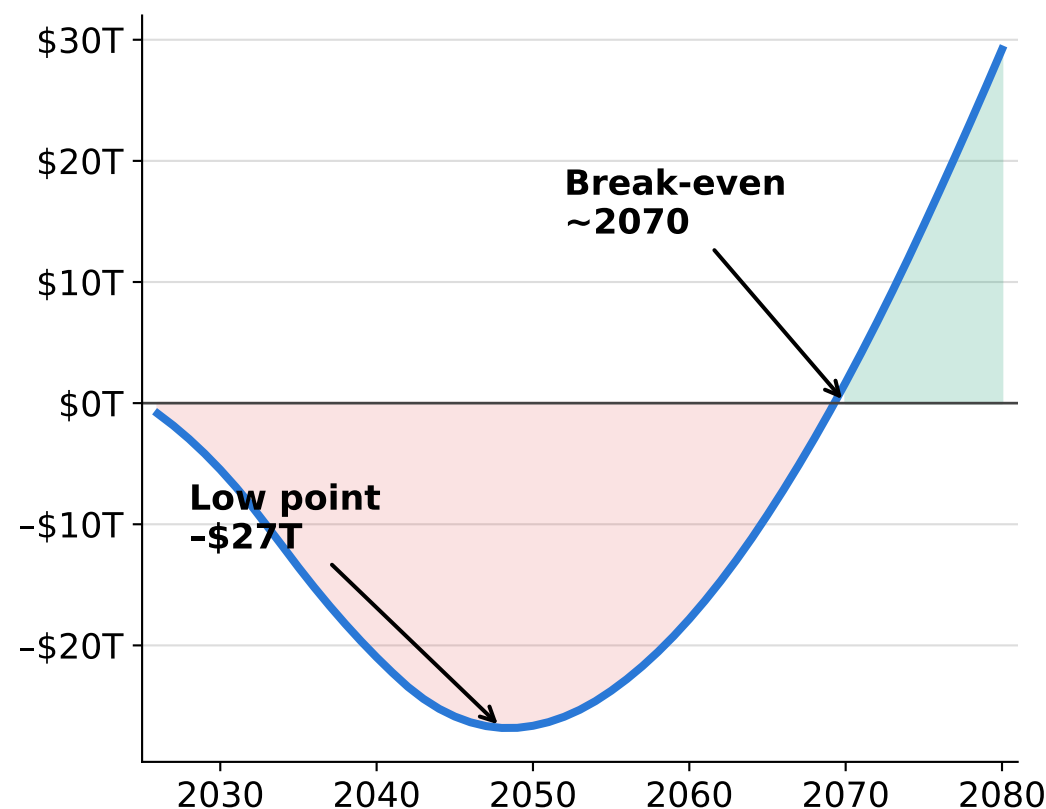
Net position by 2080

+\$29T

Annual (\$T per year)



Cumulative net (\$T)



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Illustrative model, roughly $\pm 40\%$ uncertainty. Anchored on IEA World Energy Investment 2026, McKinsey (2022) and IEA consumer energy spending data; stretched to a 2065–2080 net-zero timeline. Excludes avoided climate damages and health benefits, which would bring break-even earlier.

CO₂ Emissions to Net Zero, and the Keeling Curve

Global CO₂ on a realistic path reaching net zero around 2074

Net zero reached

~2074

CO₂ peak (~2060)

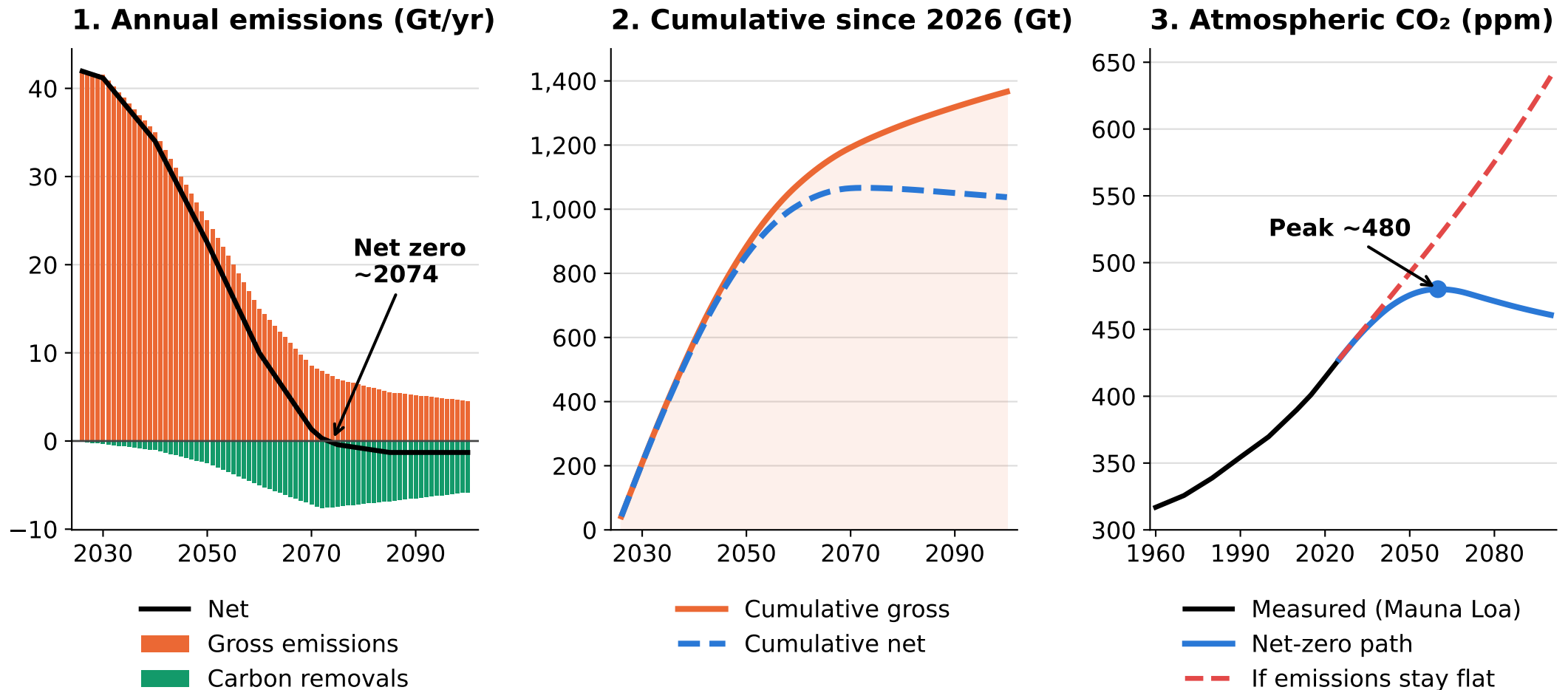
~480 ppm

Gross emitted 2026–2100

~1,370 Gt

CO₂ in 2100

~460 ppm



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Sources: Global Carbon Budget 2025 (42.2 Gt CO₂ in 2025); Scripps/NOAA Mauna Loa record. Concentrations from a simplified carbon-cycle model (Joos et al. impulse response) calibrated to 2025, with ocean/land rebound and sinks weakening with warming and cumulative uptake. Illustrative projection, not a forecast.

Global Temperature: CO₂ Emissions to Net Zero

Three paths: emissions flat, realistic net zero (~2074), and net zero with moderate carbon removal (~15 Gt/yr)

1.5 °C crossed

~2030

Peak warming, net zero

~2.1 °C

range 1.8–2.6 °C, ~2070

2100, moderate removal

~1.9 °C

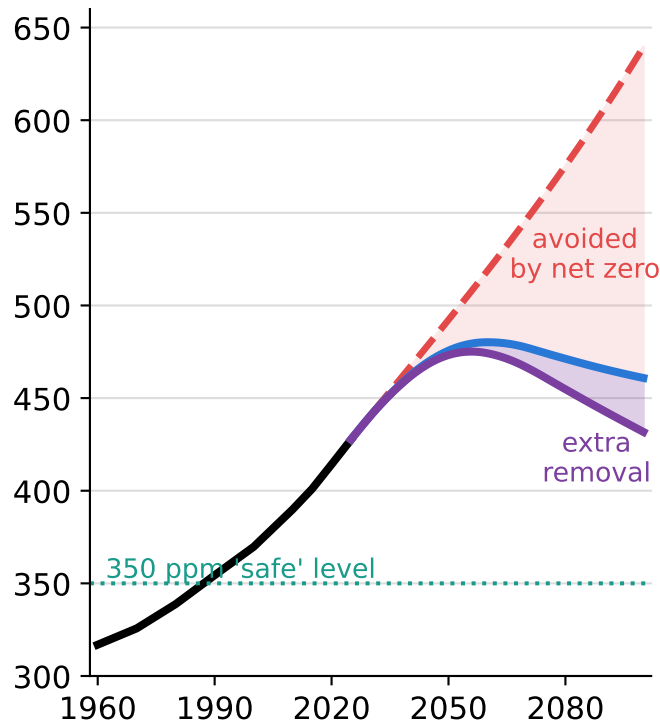
vs ~2.1 °C net zero only

2100, emissions flat

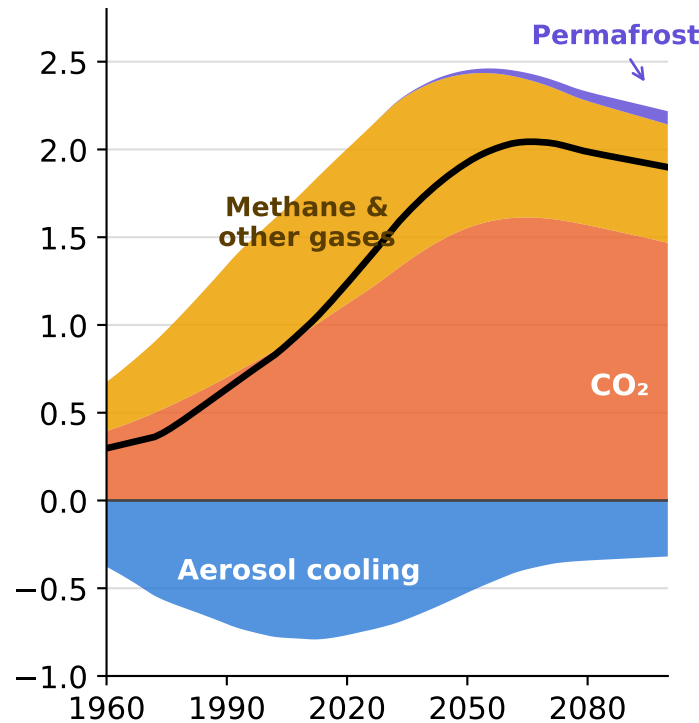
~3.0 °C

range 2.6–3.6 °C

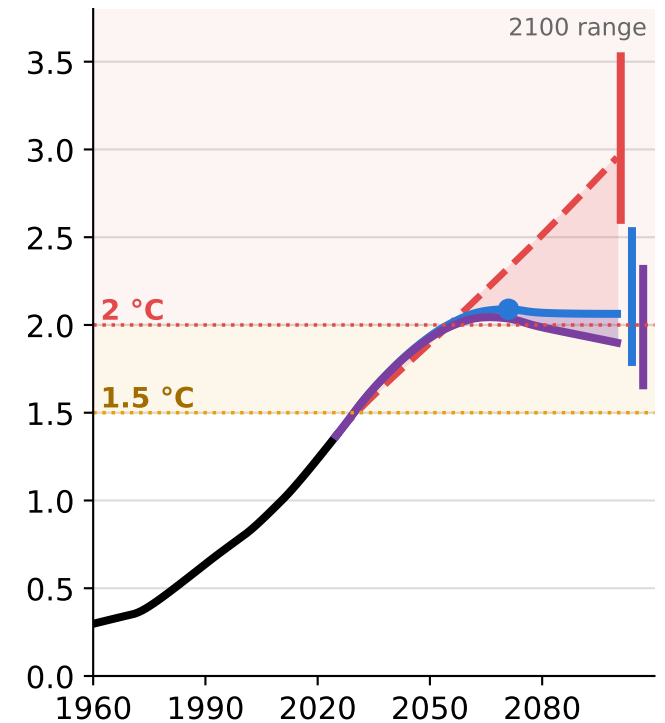
1. Atmospheric CO₂ (ppm)



2. What drives warming (°C)



3. Surface temperature (°C)



— Measured / hindcast — Net zero (~2074) CO₂ Permafrost feedback
- - - If emissions stay flat — Net zero + moderate removal Methane & other gases Aerosol cooling

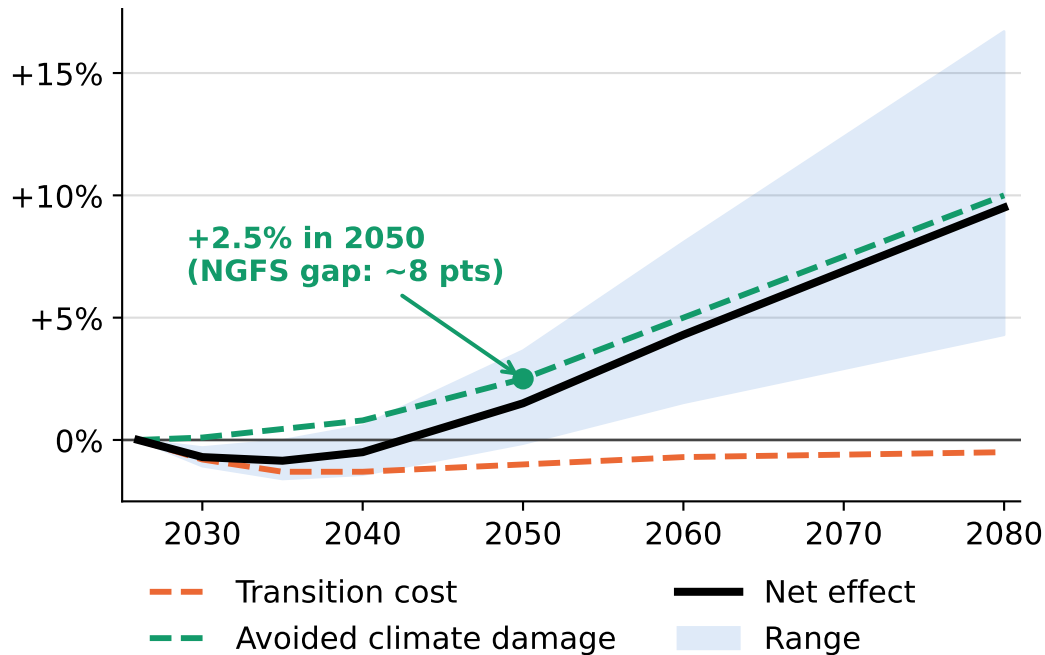
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Two-layer energy-balance model calibrated to 1.37 °C human-induced warming in 2025 (Forster et al., IGCC 2025); climate sensitivity 3 °C (range 2.5–4 °C with half- to 1.3×-strength sink weakening). Joos et al. carbon cycle with ocean/land rebound and sinks weakening with warming and cumulative uptake. Moderate removal ramps to ~15 Gt/yr by 2075 (vs ~7.6), unlike the ~85 Gt/yr “2× pace” path in the companion CDR briefing. Panel 2: moderate-removal path. Not modelled: ice-sheet collapse, abrupt permafrost thaw, AMOC shutdown, natural variability. Illustrative projection, not a forecast.

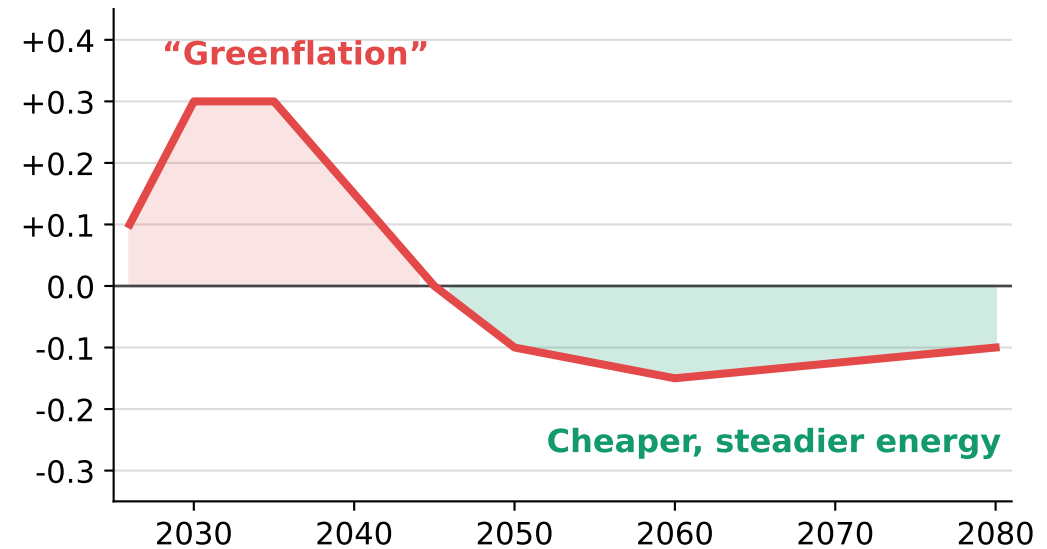
Economic Effects of the Net-Zero Path

Difference from a current-policies world, 2026–2080 (illustrative)

1. Global GDP level (% vs current policies)

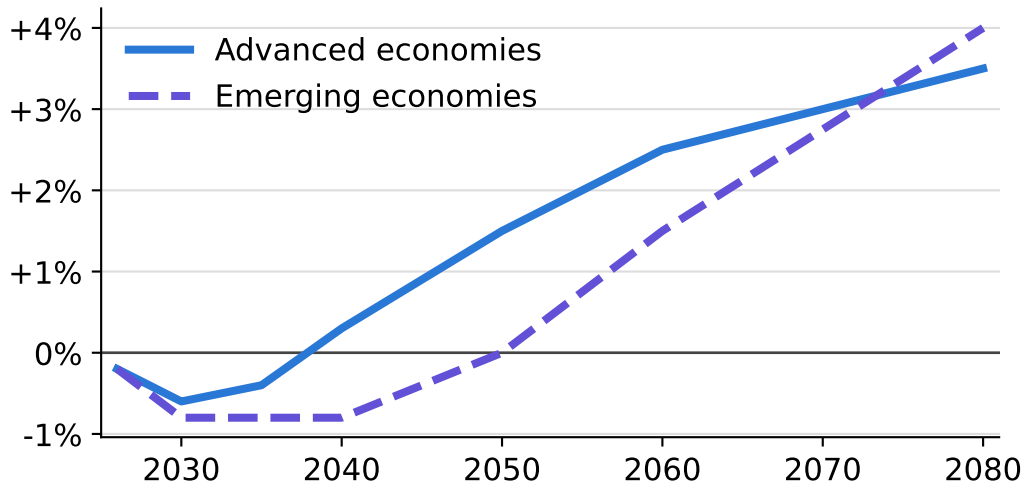


2. Inflation (percentage points)

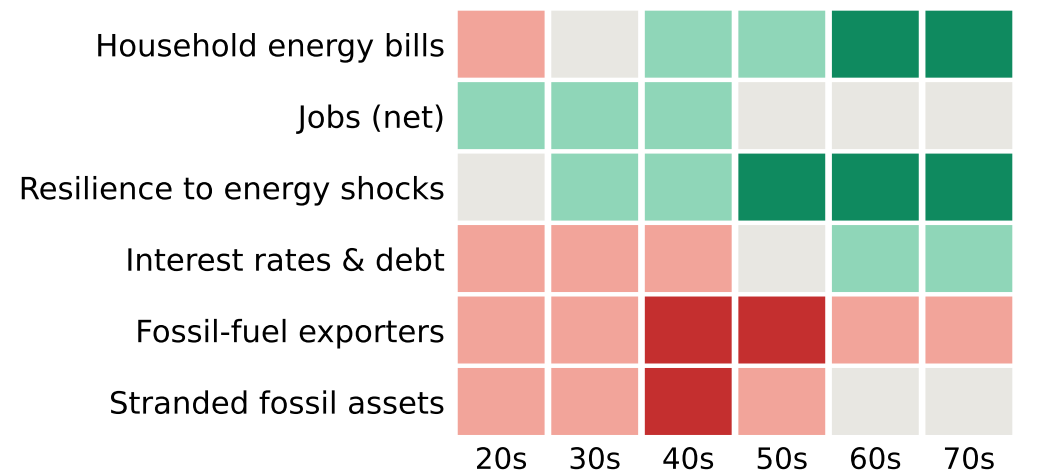


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3. Household real income (% vs current policies)



4. Other indicators (green = favorable)



Legend for 4: Strongly negative (dark red), Negative (red), Neutral (grey), Positive (light green), Strongly positive (dark green)

Anchored on IMF World Economic Outlook Oct 2022 (Ch. 3) and NGFS Phase V; scaled to a 2065–2080 net-zero timeline.