Methods Appendix

Companion to "RCP8.5 is Officially Dead"
The Honest Broker · Roger Pielke Jr. · April 2026

FaIR runs

I used FaIR v2.2.0 with the calibrated and constrained ensemble distributed by Smith et al. (2024) (parameter set 1.4.1) — the same emulator and parameter set Van Vuuren et al. (2026) used to characterize the CMIP7 set. CMIP7 emissions came from the spreadsheet supplied with the Sanderson and Smith (2025) Zenodo deposit (doi.org/10.5281/zenodo.14382495), which contains the ScenarioMIP plotting pipeline used to produce Figure 1 of Van Vuuren et al. (2026). SSP emissions came from the RCMIP v5.1 harmonized dataset. I ran each of the seven CMIP7 scenarios and each of the five tier-1 SSPs through the identical emulator setup with identical parameters.

The SSP2-4.5 result from this procedure (2.72°C, 2081–2100 mean) closely matches the AR6 published value (2.7°C), which confirms that the calibration reproduces AR6's central estimate near the middle of the scenario range. I used a subsample of 100 ensemble members for memory efficiency; medians are accurate to within approximately 0.05°C of the full ensemble.

Temperature and forcing reference table

Scenario	2100 ERF (W/m^2)	2081–2100 GSAT, same FaIR (°C)	AR6 Published GSAT (°C)
CMIP7 High	6.7	3.0	—
CMIP7 Medium	5.3	2.5	—
CMIP7 Low	3.1	1.7	—
CMIP7 Very Low	2.5	1.4	—
SSP5-8.5 (same FaIR)	—	3.9	4.4
SSP3-7.0 (same FaIR)	—	3.2	3.6
SSP2-4.5 (same FaIR)	—	2.7	2.7
SSP1-2.6 (same FaIR)	—	2.2	1.8
SSP1-1.9 (same FaIR)	—	2.0	1.4

FaIR v2.2.0 with calibration v1.4.1, ensemble median. AR6 published values from IPCC AR6 WG1 Table 4.5.

Why the same FaIR calibration runs cooler than AR6 at the high end

The temperature reference table shows that the same-FaIR numbers and the AR6 published numbers diverge most for the high and low extremes. The calibration paper underlying both Sanderson and Smith (2025) and the Van Vuuren et al. figures — Smith et al. (2024), in *Geoscientific Model Development* — addresses this divergence directly. The headline finding from their abstract:

> *"We show that two very different future projections to a given emission scenario can be obtained using emissions from the IPCC Sixth Assessment Report (AR6) (*`fair-calibrate` *v1.4.0) and from updated emission datasets through 2022 (*`fair-calibrate` *v1.4.1) for similar climate constraints in both cases."*

Smith and colleagues compared two calibrations explicitly. Version 1.4.0 uses AR6 historical emissions through 2014 with SSP projections thereafter — the AR6 setup. Version 1.4.1 uses observed historical emissions through 2022. The climate constraints themselves — equilibrium climate sensitivity, transient climate response, present-day aerosol forcing — are similar in both cases, drawn from IPCC AR6 WG1 Chapter 7. The difference between the two calibrations is dominated by what was assumed versus observed for emissions during 2015–2022.

The mechanism is straightforward. The SSP-projected emissions for 2015–2022 ran higher than what actually happened. When you constrain a probabilistic ensemble against the observed emissions trajectory plus observed warming-to-date, you get a tighter ensemble with somewhat lower projected warming for the same future emissions input. As Smith et al. put it in Section 1: "the significant impact of using different historical emission datasets for projections."

There is a second compatible mechanism Smith and colleagues flag in the same introduction. AR6's published 2081–2100 numbers were a multi-line-of-evidence assessment that included CMIP6 ESM ensemble means alongside FaIR and MAGICC. They write that "several Coupled Model Intercomparison Project (CMIP6) models have equilibrium climate sensitivity (ECS) outside of the very likely (nominal 5–95%) range assessed by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)" and that "unadjusted GMST projections from CMIP6 models are often not appropriate for understanding climate change responses to anthropogenic emissions." The AR6 synthesis carried some warmth from those high-ECS CMIP6 models that the constrained FaIR ensemble does not.

Both mechanisms pull high-emission scenarios cooler relative to AR6's published numbers. The first dominates Smith et al.'s direct test, since their v1.4.0 vs v1.4.1 comparison holds constraints similar and varies emissions data.

So the apples-to-apples comparison in the temperature table tells a different story than AR6's published numbers, and both are defensible:

- Using AR6's synthesis as the reference, the new CMIP7 High is 1.4°C cooler than SSP5-8.5 and 0.6°C cooler than SSP3-7.0.
- Using the same-FaIR comparison, the new CMIP7 High is 0.9°C cooler than SSP5-8.5 and 0.2°C cooler than SSP3-7.0.

The scenario walk-back is real either way. There is also an irony worth noting. The principal reason the new FaIR calibration produces lower 21st-century warming than AR6 is that observed emissions came in lower than the SSP scenarios projected. That is the same observation Burgess et al. (2021) and Pielke, Burgess, and Ritchie (2022) documented years earlier, and that I have written about repeatedly at *The Honest Broker*. The IAM community has now formalized in technical detail, in *Geoscientific Model Development*, the same critique they spent years deflecting when other people raised it.

Species-by-species comparison: CMIP7 vs SSP analogues

Three supplementary tables on the following pages present a comprehensive comparison across all fourteen emission species in the CMIP7 spreadsheet, paired against each scenario's nearest SSP analogue. They expand the headline cumulative-CO_2 table from the body of the post into the full species-level view.

Each cell in the species tables shows the CMIP7 marker scenario value, the SSP analogue value, and the percentage difference. Color coding indicates direction and magnitude: blue when CMIP7 sits below the SSP analogue, yellow or red when CMIP7 sits above, white when within ±5%.

Three patterns stand out across these tables

By 2100, most non-CO_2 species converge on identical values between CMIP7 and the SSP analogue. CH_4, N_2O, sulfur, NOx, NH_3, BC and others all show “+0%” across most pairings at 2100. The IAM teams ran their existing SSP-based models to common endpoint values for non-CO_2 species, so the action at 2100 is concentrated in CO_2. The trajectory shape — when those endpoints are reached — differs more than the endpoints themselves.

CMIP7 reduces aerosols and air pollutants in mid-century relative to the SSP analogues, particularly in the High scenario. Black carbon down 35 percent at both 2050 and 2100. Organic carbon down 23 percent. NOx down 13 percent. Sulfur down 12 percent. This reflects updated air pollution control assumptions and partially offsets the GHG-forcing reduction through reduced aerosol cooling. It is one reason the new High does not produce as much temperature reduction as the cumulative CO_2 reduction alone would imply.

CMIP7 has weaker AFOLU sinks across the board. The starkest case is CMIP7 Low, which has +136 Gt cumulative AFOLU CO_2 versus SSP1-2.6's −115 Gt — a 251 Gt swing. The CMIP7 framework has scaled back the optimistic land-based CDR assumptions that defined SSP1's sustainability storyline. The recent literature on land-based CDR feasibility supports the more conservative position. This is a substantive update, and largely an honest one.

One outlier worth flagging: SF_6 runs 22 to 77 percent higher in CMIP7 than in the SSP analogues across all four pairings. The absolute climate impact is modest given the small mass involved, but the systematic exceedance is the only species where CMIP7 routinely sits above its SSP analogue. The plausibility logic for less aggressive SF_6 control is unclear from the design paper.

The cumulative CO_2 table summarizes the totals from 2020 to 2100, broken into FFI and AFOLU components. The headline number is the +18 percent gap between CMIP7 Medium and SSP2-4.5 on cumulative FFI. CMIP7 Medium emits more cumulative CO_2 from energy and industry than SSP2-4.5 did, despite CMIP7 Medium having slightly cooler 2081–2100 mean warming. The trajectory shape — CMIP7 Medium continues rising while SSP2-4.5 declines — explains the apparent paradox and is treated in the body of the post.

Table 1. Emissions at 2050

CMIP7 vs SSP (AR6) Emissions at 2050: CMIP7 / SSP (Δ%)

Species	Unit	High vs SSP3-7.0	Medium vs SSP2-4.5	Low vs SSP1-2.6	Very Low vs SSP1-1.9
CO_2 FFI	Gt CO_2/yr	54.3 / 60.0 (-10%)	40.9 / 43.0 (-5%)	19.2 / 19.7 (-3%)	3.3 / 2.9 (+14%)
CO_2 AFOLU	Gt CO_2/yr	3.3 / 2.9 (+14%)	1.4 / 0.5 (+180%)	2.2 / -1.8 (-222%)	0.5 / -0.8 (-162%)
CH_4	Mt CH_4/yr	525 / 559 (-6%)	352 / 357 (-1%)	225 / 211 (+7%)	181 / 170 (+6%)
N_2O	Mt N_2O/yr	16.0 / 15.6 (+3%)	13.2 / 12.6 (+5%)	9.0 / 7.9 (+14%)	9.0 / 8.1 (+11%)
Sulfur	Mt SO_2/yr	88 / 100 (-12%)	52 / 53 (-2%)	27 / 27 (+0%)	23 / 22 (+5%)
NOx	Mt NO_2/yr	154 / 176 (-12%)	114 / 123 (-7%)	77 / 81 (-5%)	53 / 55 (-4%)
CO	Mt CO/yr	825 / 996 (-17%)	654 / 731 (-11%)	510 / 503 (+1%)	455 / 447 (+2%)
NH_3	Mt NH_3/yr	78 / 81 (-4%)	74 / 76 (-3%)	64 / 64 (+0%)	65 / 65 (+0%)
VOC	Mt VOC/yr	214 / 256 (-16%)	176 / 197 (-11%)	115 / 109 (+6%)	98 / 93 (+5%)
BC	Mt BC/yr	7.1 / 11.0 (-35%)	5.6 / 6.3 (-11%)	3.5 / 3.6 (-3%)	2.7 / 2.8 (-4%)
OC	Mt OC/yr	30 / 38 (-21%)	22 / 27 (-19%)	17 / 18 (-6%)	16 / 17 (-6%)
CF_4	kt CF_4/yr	5.3 / 7.8 (-32%)	7.0 / 9.5 (-26%)	1.6 / 2.3 (-30%)	1.7 / 2.3 (-26%)
SF_6	kt SF_6/yr	10.4 / 8.5 (+22%)	3.6 / 2.5 (+44%)	3.6 / 2.1 (+71%)	3.9 / 2.2 (+77%)
HFC-134a	kt/yr	192 / 201 (-4%)	115 / 136 (-15%)	14 / 15 (-7%)	15 / 15 (+0%)

Source: CMIP7 ScenarioMIP (Van Vuuren et al. 2026); RCMIP v5.1 SSP harmonized emissions.
Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

Table 2. Emissions at 2100

CMIP7 vs SSP (AR6) Emissions at 2100: CMIP7 / SSP (Δ%)

Species	Unit	High vs SSP3-7.0	Medium vs SSP2-4.5	Low vs SSP1-2.6	Very Low vs SSP1-1.9
CO_2 FFI	Gt CO_2/yr	71.3 / 80.1 (-11%)	44.6 / 14.5 (+208%)	-3.3 / -5.7 (-42%)	-9.8 / -11.5 (-15%)
CO_2 AFOLU	Gt CO_2/yr	2.9 / 2.7 (+7%)	-4.4 / -4.8 (-8%)	0.0 / -2.9 (-100%)	-1.7 / -2.4 (-29%)
CH_4	Mt CH_4/yr	778 / 778 (+0%)	295 / 295 (+0%)	122 / 122 (+0%)	112 / 112 (+0%)
N_2O	Mt N_2O/yr	20.6 / 20.6 (+0%)	8.7 / 8.7 (+0%)	8.4 / 8.4 (+0%)	8.3 / 8.3 (+0%)
Sulfur	Mt SO_2/yr	78 / 78 (+0%)	31 / 31 (+0%)	8 / 8 (+0%)	9 / 9 (+0%)
NOx	Mt NO_2/yr	151 / 151 (+0%)	82 / 82 (+0%)	47 / 47 (+0%)	43 / 43 (+0%)
CO	Mt CO/yr	837 / 915 (-9%)	365 / 385 (-5%)	356 / 353 (+1%)	349 / 346 (+1%)
NH_3	Mt NH_3/yr	88 / 88 (+0%)	65 / 65 (+0%)	63 / 63 (+0%)	63 / 63 (+0%)
VOC	Mt VOC/yr	209 / 228 (-8%)	114 / 121 (-6%)	64 / 62 (+3%)	60 / 59 (+2%)
BC	Mt BC/yr	5.9 / 9.1 (-35%)	2.7 / 2.7 (+0%)	2.2 / 2.2 (+0%)	2.1 / 2.1 (+0%)
OC	Mt OC/yr	30 / 34 (-12%)	13 / 15 (-13%)	13 / 13 (+0%)	13 / 13 (+0%)
CF_4	kt CF_4/yr	5.1 / 6.0 (-15%)	2.8 / 3.2 (-13%)	0.8 / 0.9 (-11%)	0.8 / 0.9 (-11%)
SF_6	kt SF_6/yr	11.6 / 9.5 (+22%)	1.1 / 0.8 (+38%)	1.5 / 0.9 (+67%)	1.6 / 0.9 (+78%)
HFC-134a	kt/yr	268 / 281 (-5%)	130 / 154 (-16%)	17 / 18 (-6%)	19 / 18 (+6%)

Source: CMIP7 ScenarioMIP (Van Vuuren et al. 2026); RCMIP v5.1 SSP harmonized emissions.
Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

Table 3. Cumulative CO_2 emissions, 2020–2100

Cumulative CO_2 Emissions, 2020–2100 (Gt CO_2)

Pairing	CMIP7 FFI	SSP FFI	Δ% FFI	CMIP7 AFOLU	SSP AFOLU	CMIP7 Total	SSP Total
High vs SSP3-7.0	4,629	5,074	-9%	+276	+248	4,906	5,322
Medium vs SSP2-4.5	3,361	2,842	+18%	-4	-68	3,357	2,775
Low vs SSP1-2.6	1,132	1,112	+2%	+136	-115	1,268	997
Very Low vs SSP1-1.9	276	320	-14%	+33	-63	309	257

Source: CMIP7 ScenarioMIP (Van Vuuren et al. 2026); RCMIP v5.1 SSP harmonized emissions.
Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

Data sources

CMIP7 emissions: spreadsheet supplied with the Sanderson and Smith (2025) Zenodo deposit (doi.org/10.5281/zenodo.14382495), the data and pipeline used to produce Figure 1 of Van Vuuren et al. (2026). SSP emissions: RCMIP v5.1 harmonized dataset. Annual values are interpolated where source data is decadal.

Where these scenarios are used in high-level policy

The retreat from RCP8.5 in CMIP7 is not a small or academic matter. RCP8.5, SSP5-8.5, and SSP3-7.0 are embedded in the statutory adaptation regimes of most of the world's largest economies and in the climate stress tests that govern hundreds of billions of dollars in bank capital. The table on the following page documents eighteen examples of high-end-scenario use in national impact assessments, multilateral frameworks, and central-bank stress tests.

Three patterns are worth noting. First, national impact assessments in the United States, United Kingdom, Germany, Canada, Australia, Japan, and the Netherlands have all leaned on RCP8.5 or SSP5-8.5 as their high-end scenario, often justified explicitly on precautionary grounds. The German Umweltbundesamt's selection of RCP8.5 "aus Vorsorgegründen" ("on precautionary grounds") for the KWRA 2021 is the cleanest example. Second, the Network for Greening the Financial System (NGFS) framework, used by 140+ central banks, exports a Hot House World scenario calibrated to RCP8.5 physical risk into the bank stress tests run by the European Central Bank, Bank of England, Reserve Bank of New Zealand, Banque de France, and the US Federal Reserve. Third, the World Bank's Climate Change Knowledge Portal, which provides the climate diagnostics for over 100 client countries' development reports, defaults to SSP5-8.5 and SSP3-7.0.

If the new CMIP7 set communicates a quieter implicit message about the high end of plausible emissions, that message will need to propagate through this entire infrastructure before it changes how adaptation budgets are sized, building codes are written, and bank capital is held.

High-Level Policy Uses of RCP8.5, SSP5-8.5, and SSP3-7.0

Jurisdiction / Institution	Policy document / programme	Year	Scenarios used	Application
United States	NCA4 (2018) and NCA5 (2023)	2018, 2023	RCP8.5; SSP5-8.5	Statutory national impact assessment (GCRA)
United Kingdom	UKCP18 / CCRA3 / CCRA4	2018-2025	RCP8.5; SSP5-8.5; SSP3-7.0	National adaptation planning and risk assessment
European Union	EU Adaptation Strategy COM(2018)738; JRC PESETA	2018	RCP8.5 + SSP5	EU-wide impact projections and policy analysis
Germany	KWRA 2021; Federal Climate Adaptation Act	2021, 2024	RCP8.5	Precautionary; underpins federal adaptation law
Canada	Canada's Changing Climate Report	2019, 2021	RCP8.5	National assessment; building-code climate inputs
Australia	ESCI, NARCliM1.5; National Climate Risk Asmt.	2020-2024	RCP8.5	Federal/state risk; financial-disclosure standard
Japan	Climate Change Adaptation Plan; S-18 Project	2021-ongoing	RCP8.5; SSP5-8.5	Statutory impact assessment under Adaptation Act
Netherlands	KNMI'14 / KNMI'23 scenarios; Delta Programme	2014, 2023	RCP8.5; SSP5-8.5; SSP3-7.0	National flood, water and spatial-adaptation planning
Tokyo Metropolitan Gov.	Tokyo Climate Change Adaptation Plan	2019, 2021	RCP8.5	Sub-national adaptation planning (population ~14m)
NGFS (140+ central banks)	NGFS Climate Scenarios, Phases IV-V	2023-2024	NGFS Hot House World	Reference framework for central-bank stress testing
European Central Bank	Economy-wide CST; 2022 Supervisory CST	2021-2024	NGFS Hot House World	Stress test of 112 European banks; SREP capital guidance
Bank of England	Climate Biennial Exploratory Scenario (CBES)	2022	NGFS Hot House World	Stress test of UK banks and insurers (30-year horizon)
Reserve Bank of New Zealand	2023 Climate Stress Test ("Too Little, Too Late")	2023	NGFS Hot House World	Stress test of 5 largest NZ banks (~90% of bank loans)
US Federal Reserve	Pilot Climate Scenario Analysis	2023	NGFS scenarios	Pilot exercise with 6 largest US banks
Banque de France (ACPR)	30-year climate pilot stress test	2021	NGFS Hot House World	Stress test of French banks and insurers
World Bank	Country Climate & Development Reports; CCKP	ongoing	SSP5-8.5; SSP3-7.0	Climate diagnostics for 100+ client countries
FAO	Global Climate Risk Datasets	2022	SSP5-8.5	Agricultural and food-security risk maps
US EPA	EnviroAtlas "Changes Over Time"	2024-25	RCP8.5; SSP5-8.5	Federal regulatory and analytical baseline

Sources: NCA4/NCA5 (USGCRP); UKCP18 / CCRA Adaptation Reporting (Defra/CCC); EU COM(2018)738; UBA KWRA 2021; CCCR (ECCC/NRCan); ESCI / NCRA (DCCEEW); MOE Japan; KNMI; NGFS Phase IV/V; ECB OP No. 281; Bank of England CBES; RBNZ CST 2023; Federal Reserve Pilot CSA; Banque de France/ACPR; World Bank CCKP and CCDRs; FAO Global Climate Risk Datasets; US EPA EnviroAtlas. Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

SSP populations: AR6 vs the 2024 update

The CMIP7 design team did not just inherit the SSP storylines and emissions structure from AR6. They also inherited — and updated — the population trajectories underlying each scenario. AR6 used the population scenarios from KC and Lutz (2014), known as WIC2013, drawn from the 2010 census round and UN WPP2010. The 2024 update, KC et al. (2024) IIASA Working Paper WP-24-003, known as WIC2023, comes from the same Wittgenstein Centre/IIASA team. The base year shifted from 2010 to 2020. Fertility, mortality, and migration assumptions were revised against observed 2015-2022 data.

Two findings from the update bear on the new scenario set. First, child mortality declined faster than WIC2013 anticipated, especially in countries with high HIV and AIDS prevalence; the number of high-mortality countries fell from 67 to 52 between the two assessments. Second, fertility declined slower than projected in medium- and high-fertility countries, particularly in sub-Saharan Africa. Africa alone accounts for most of the upward revision: 3.55 billion in 2100 in WIC2023 versus 2.62 billion in WIC2013, a 35 percent increase.

The implications differ across SSPs. SSP1 and SSP5 trajectories barely move — both produce nearly identical low-fertility/low-mortality futures with peaks around 8.5 billion in 2050 and decline to 7.4 billion by 2100. SSP2 rises by 10 percent at 2100. SSP3 and SSP4 — the high-population pathways — rise substantially. SSP3, the storyline underlying the new CMIP7 High scenario, now reaches 14.5 billion in 2100 versus 12.6 billion in WIC2013.

Table 5 summarizes the comparison.

SSP 2100 Population: AR6 (WIC2013) vs 2024 Update (WIC2023)

SSP scenario	WIC2013 (2100, bn)	WIC2023 (2100, bn)	Change (billion)	Change (%)
SSP1 (Sustainability)	6.9	7.4	+0.5	+7%
SSP2 (Middle of the Road)	9.0	9.9	+0.9	+10%
SSP3 (Regional Rivalry)	12.6	14.5	+1.9	+15%
SSP4 (Inequality)	9.3	13.3	+4.0	+43%
SSP5 (Fossil-fuelled)	7.4	7.4	0.0	0%

WIC2013: KC and Lutz (2014, 2017), used in IPCC AR6 WGI/WGII/WGIII.
WIC2023: KC et al. (2024), IIASA Working Paper WP-24-003 (the 2024 update).
Values rounded to 0.1 bn. SSP1 and SSP5 are nearly identical in both versions.
Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

Counterfactual: CMIP7 High with SSP1/SSP5 population

The new CMIP7 High scenario uses the SSP3 storyline and therefore carries the SSP3-derived population trajectory: starting at 7.8 billion in 2020, growing monotonically to 14.5 billion in 2100, with a time-average over 2020-2100 of approximately 11 billion. The High emits 4,629 gigatons of fossil fuel and industry CO_2 cumulatively over that period.

A useful sensitivity analysis: hold the per-capita CO_2 emissions intensity of the High scenario constant — about 5.2 tonnes of CO_2 per person per year averaged across the century — and replace the population trajectory with the SSP1/SSP5 trajectory, which peaks at 8.5 billion in 2050 and declines to 7.4 billion by 2100, with a time-average of approximately 8 billion. The cumulative fossil fuel and industry CO_2 in this counterfactual scales with the population ratio:

- Population ratio (SSP1/SSP3 averages): 8.0 / 11.1 ≈ 0.72
- Counterfactual cumulative FFI CO_2: 4,629 × 0.72 ≈ 3,330 Gt (a reduction of about 1,300 Gt, or 28 percent)
- Avoided warming via AR6 Transient Climate Response to cumulative Emissions (TCRE), central estimate 0.45°C per 1000 Gt CO_2: 1,300 × 0.45/1000 ≈ 0.6°C; AR6 likely range gives 0.4–0.8°C
- Counterfactual 2081-2100 GSAT: approximately 2.4°C, down from 3.0°C

The implication is striking. With the SSP1/SSP5 population trajectory, the new CMIP7 High scenario would deliver roughly the same warming as the new CMIP7 Medium (2.5°C, 2081-2100 mean) — or a bit cooler. Roughly 0.6°C of the High scenario's projected warming traces directly to the SSP3 population assumption, not to per-capita energy or emissions intensity. The IAM modelers did not have to inflate per-capita emissions to construct a high-warming scenario; the demographic assumption did most of the work.

Caveats. This is a sensitivity analysis, not a coherent scenario. Combining the SSP3 emissions intensity (regional rivalry, slow technological development, resource-intensive lifestyles among those who can afford them) with the SSP1/SSP5 population (rapid socioeconomic development, high education, low fertility) is internally inconsistent — it asks what the SSP3 emissions trajectory would produce in a world that demographically resembles SSP1. The exercise is meant to show how much of the High scenario's cumulative carbon budget is driven by the population assumption alone, not to propose a new scenario. The calculation also holds non-CO_2 forcers and AFOLU emissions constant, rescaling only fossil fuel and industry CO_2.

CMIP7 Medium vs SSP2-4.5: GSAT trajectory comparison

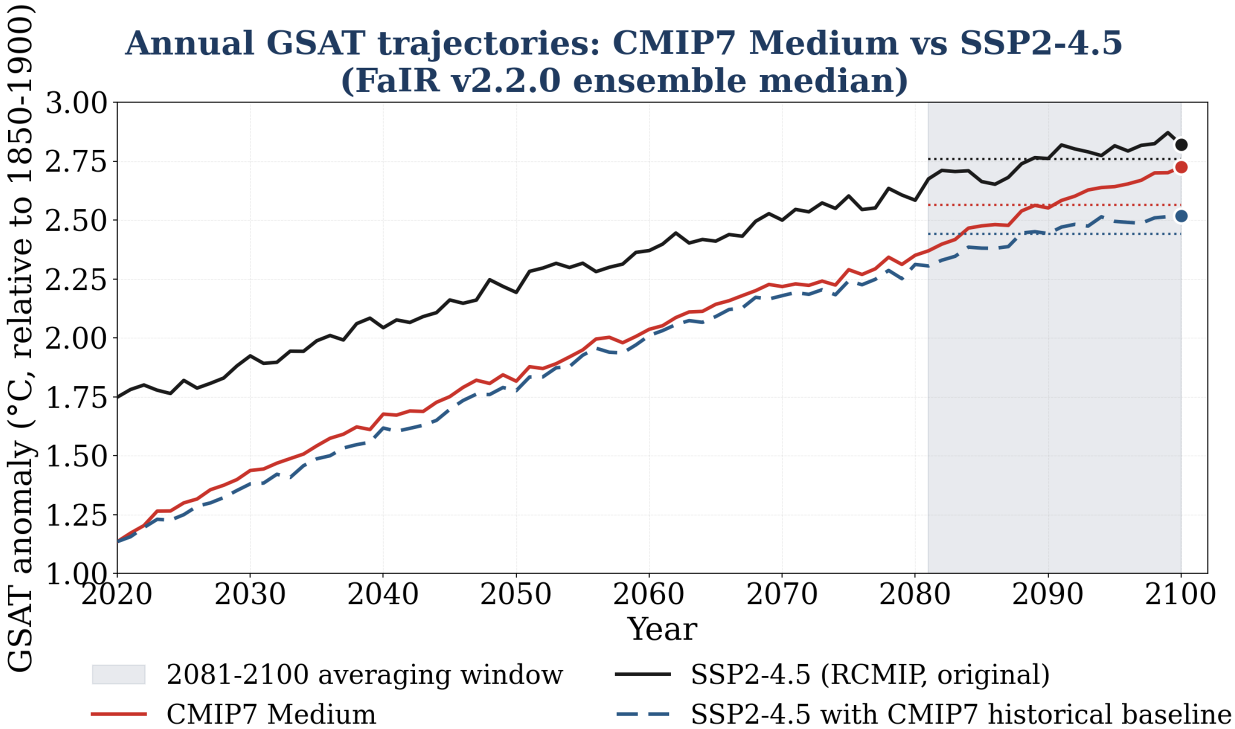
The 2081-2100 GSAT means reported in the temperature/forcing reference table show CMIP7 Medium at 2.5°C and SSP2-4.5 (run through the same FaIR ensemble) at 2.7°C. Taken at face value, the new Medium appears to be the cooler scenario despite carrying ~520 Gt more cumulative fossil CO_2 and a higher 2100 ERF (5.3 W/m^2 versus the SSP2-4.5 nominal 4.5 W/m^2). On TCRE alone, CMIP7 Medium should be roughly 0.26°C warmer than SSP2-4.5, not 0.2°C cooler. The non-CO_2 species cannot explain the difference: at 2100 they are essentially identical between the two scenarios (both inherit the SSP2 storyline), and at 2050 CMIP7 Medium's aerosol precursors (SO_2, BC, OC, NOx, CO) are actually lower than SSP2-4.5's, which would push CMIP7 Medium toward *more* warming, not less.

The figure on the next page resolves the puzzle. Annual GSAT trajectories are shown for three scenarios: CMIP7 Medium (red, solid), SSP2-4.5 as released in RCMIP v5.1.0 (black, solid), and a hybrid scenario (dashed dark blue) that splices CMIP7 medium-extension historical emissions through 2020 with SSP2-4.5 emissions from 2021 onward. All three are run through the same FaIR v2.2.0 calibrated ensemble (Smith et al. 2024, calibration v1.4.1), with 100 members sampled at random_state=42 and solar/volcanic forcing zeroed.

Two findings are immediate. First, the original SSP2-4.5 trajectory starts approximately 0.6°C above CMIP7 Medium at 2020 — not because the 21st century plays out differently in the two scenarios, but because the SSP framework harmonizes historical emissions to 2014 while CMIP7 harmonizes to 2023. The SSP-era inputs imply a present-day climate roughly 0.6°C warmer than what observations actually show, and that head start propagates through the entire trajectory. CMIP7 Medium, run with updated historical emissions, sits at 1.13°C at 2020 — close to the observed value of approximately 1.1°C.

Second, when SSP2-4.5's post-2020 emissions are run from CMIP7's historical baseline (the dashed blue curve), the picture inverts. The hybrid produces a 2081-2100 mean of 2.44°C against CMIP7 Medium's 2.56°C, with single-year 2100 values of 2.52°C and 2.72°C respectively. On a true apples-to-apples comparison anchored to the same observed 2020 baseline, CMIP7 Medium delivers approximately 0.12–0.20°C *more* warming than SSP2-4.5 — exactly what its larger cumulative CO_2 budget predicts under TCRE. The headline "Medium = 2.5°C, SSP2-4.5 = 2.7°C" comparison reverses the actual physics. The new Medium is the warmer scenario, not the cooler one; its apparent cooler reading is an artifact of stale historical emissions in the SSP-era inputs.

Annual GSAT trajectories, 2020-2100



Source: FaIR v2.2.0 with calibration v1.4.1 (Smith et al. 2024); 100-member calibrated ensemble. CMIP7 emissions from Van Vuuren et al. (2026); SSP emissions from RCMIP v5.1.0. The hybrid scenario uses CMIP7 medium-extension historical emissions through 2020 spliced with SSP2-4.5 emissions from 2021. Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

CMIP7 Medium vs SSP2-4.5: GSAT Reference Values

Scenario	2081-2100 mean (°C)	2100 single-year (°C)	2020 starting point (°C)
CMIP7 Medium	2.56	2.72	1.13
SSP2-4.5 (RCMIP, original)	2.76	2.82	1.75
SSP2-4.5 (CMIP7 historical baseline)	2.44	2.52	1.13

Source: FaIR v2.2.0 with calibration v1.4.1 (Smith et al. 2024); 100-member calibrated ensemble. CMIP7 emissions from Van Vuuren et al. (2026); SSP emissions from RCMIP v5.1.0. The hybrid scenario splices CMIP7 medium-extension historical emissions through 2020 with SSP2-4.5 emissions from 2021, isolating post-2020 trajectory dynamics from the historical-harmonization difference between datasets. Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.

Methods note: the hybrid scenario

The hybrid scenario is a synthetic construction that does not appear in any published scenario set. Its purpose is purely diagnostic — to isolate the post-2020 trajectory dynamics of SSP2-4.5 from the historical-data confound introduced by the older harmonization year used in the SSP framework. The construction takes the CMIP7 medium-extension emissions for the historical period (1750 through 2020, inclusive) and splices SSP2-4.5's emissions onto the trajectory beginning in 2021. The splice is applied uniformly across all emitted species. The hybrid is then run through the same FaIR ensemble used for the CMIP7 Medium and original SSP2-4.5 runs, with no other modifications.

The hybrid is not proposed as a coherent scenario. The CMIP7 medium-extension and SSP2-4.5 do share an underlying SSP2 storyline (per Van Vuuren et al. 2026, §3.3), so the splice does not produce wildly inconsistent emissions at 2020. But the historical period that CMIP7 uses reflects updated bottom-up inventory data that the SSP-era inputs do not. The exercise is therefore best read as answering the question: *if SSP2-4.5's post-2020 emission projections were run from the same historical baseline as CMIP7's scenarios, how would they compare?* The answer, as the figure above shows, is that SSP2-4.5 would project approximately 0.1–0.2°C less warming by 2100 than CMIP7 Medium — consistent with cumulative-emissions accounting and with TCRE.

A separate finding worth flagging: the 0.6°C head start that SSP2-4.5 exhibits at 2020 in the original RCMIP run implies that the AR6-era scenarios, as commonly distributed and emulated, were already telling a hotter story about the present-day climate than observations support. This is a property of the harmonized SSP emissions data sets, not of the SSP narratives themselves. CMIP7's harmonization to 2023 observations corrects this. Users of SSP-era scenarios for impact assessment, hazard analysis, or financial-stress testing should be aware that any default trajectory anchored to 2014 inputs will systematically overstate present-day warming by something on the order of half a degree.

References

Burgess, M. G., Ritchie, J., Shapland, J., and Pielke, R. Jr. (2021). IPCC baseline scenarios have over-projected CO_2 emissions and economic growth. *Environmental Research Letters*, 16, 014016. https://doi.org/10.1088/1748-9326/abcdd2

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

K.C., S. and Lutz, W. (2017). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. *Global Environmental Change*, 42, 181–192. https://doi.org/10.1016/j.gloenvcha.2014.06.004

K.C., S., Dhakad, M., Potancokova, M., Adhikari, S., Yildiz, D., Mamolo, M., Sobotka, T., Zeman, K., Abel, G., Lutz, W., and Goujon, A. (2024). Updating the Shared Socioeconomic Pathways (SSPs) Global Population and Human Capital Projections. *IIASA Working Paper*, WP-24-003. https://pure.iiasa.ac.at/19487

Pielke, R. Jr., Burgess, M. G., and Ritchie, J. (2022). Plausible 2005–2050 emissions scenarios project between 2°C and 3°C of warming by 2100. *Environmental Research Letters*, 17, 024027. https://doi.org/10.1088/1748-9326/ac4ebf

Sanderson, B. and Smith, C. (2025). *Indicative ScenarioMIP emissions and climate projections* [Software/dataset]. Zenodo. https://doi.org/10.5281/zenodo.14382495

Smith, C., Cummins, D. P., Fredriksen, H.-B., Nicholls, Z., Meinshausen, M., Allen, M., Jenkins, S., Leach, N., Mathison, C., and Partanen, A.-I. (2024). fair-calibrate v1.4.1: calibration, constraining, and validation of the FaIR simple climate model for reliable future climate projections. *Geoscientific Model Development*, 17, 8569–8592. https://doi.org/10.5194/gmd-17-8569-2024

Van Vuuren, D. P., O'Neill, B. C., Tebaldi, C., et al. (2026). The Scenario Model Intercomparison Project for CMIP7 (ScenarioMIP-CMIP7). *Geoscientific Model Development*, 19, 2627–2656. https://doi.org/10.5194/gmd-19-2627-2026

Produced at the direction of Roger Pielke Jr. at The Honest Broker on Substack.