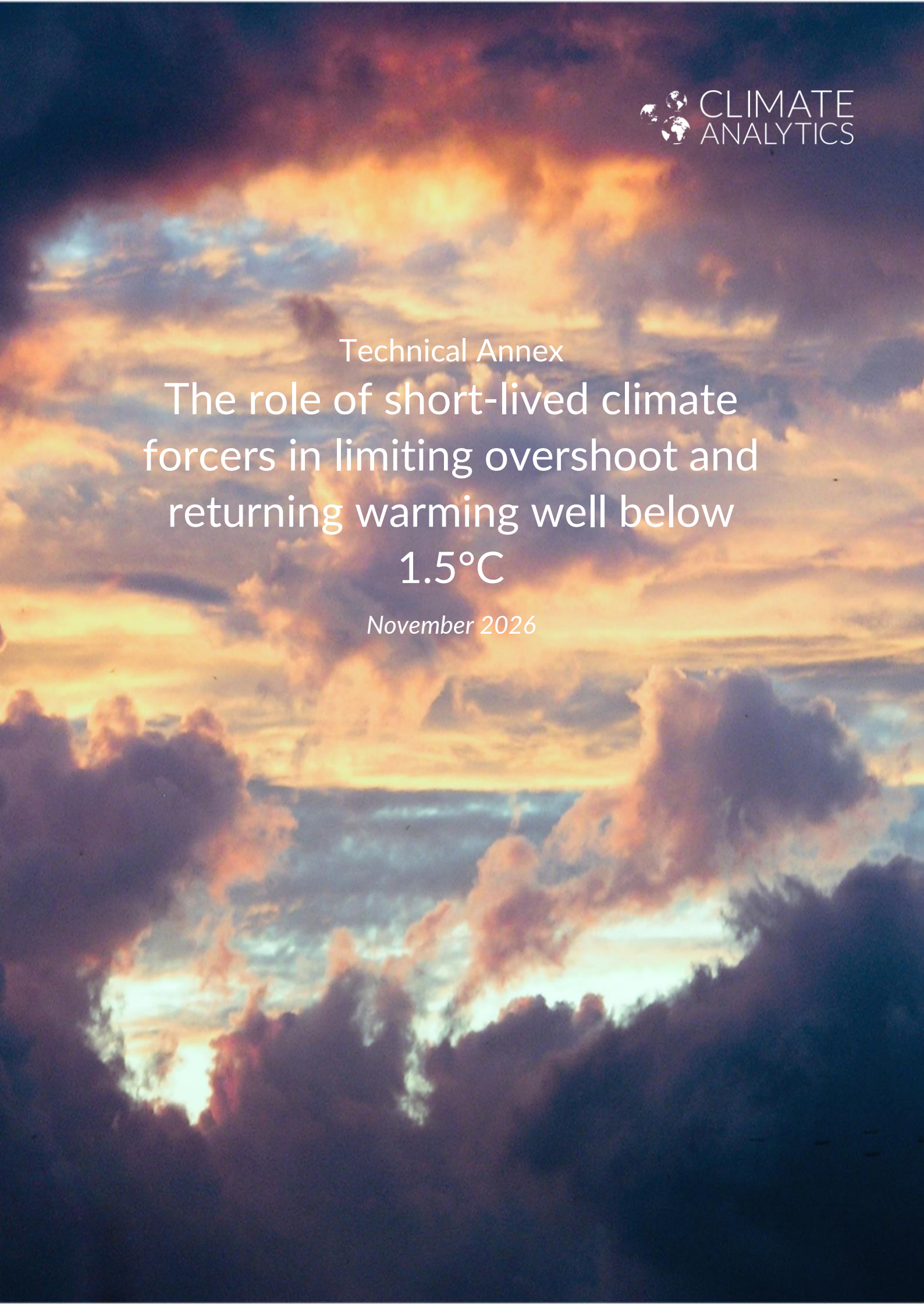


CLIMATE ANALYTICS

Technical Annex

The role of short-lived climate forcers in limiting overshoot and returning warming well below 1.5°C

November 2026

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About Climate Analytics

Climate Analytics is a global climate science and policy institute. Our mission is to deliver cutting-edge science, analysis and support to accelerate climate action and keep warming below 1.5°C.

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1. Introduction

With global temperatures currently on track to exceed the Paris Agreement's 1.5°C limit, decision-makers urgently require robust, up-to-date evidence to guide policies that minimise the magnitude and duration of this temperature overshoot. To address this need, Climate Analytics, with the support of the Super Pollutant Action Alliance, undertook a new study to assess the role of different mitigation levers in slowing the rate of warming, limiting temperature overshoot, and returning temperatures back below 1.5°C this century. In particular, this study explores the impact of targeted mitigation of short-lived climate forcers (SLCFs), the transition away from fossil fuels (TAFF), land-sector mitigation (LULUCF), and novel carbon dioxide removal (CDR).

The research addresses four key questions:

1. What are the temperature benefits of targeted SLCF mitigation?
2. How do TAFF, LULUCF, and novel CDR compare with targeted SLCF mitigation, and which combination of levers is needed to return warming to below 1.5°C by 2100?
3. Which targeted SLCF actions deliver the greatest additional temperature benefit and on which timescale?
4. How much additional warming is unmasked as cooling aerosols decline alongside decarbonisation?

This technical annex accompanies a briefing, which addresses the first three research questions. This technical annex provides the supporting figures, tables, sensitivity analyses, and additional data, including the Intermediate Ambition Scenario and Policy-failure pathway sensitivities not discussed in the briefing. It also summarises findings on aerosol unmasking.

This technical annex is structured as follows: Section 2 provides a background on SLCFs and their role in limiting global warming, Section 3 presents a detailed description of the methodology used in this study, and Section 4 provides more data and analysis on each research question. Further technical details are provided in the Annexes.

2. Background

SLCFs are a diverse group of aerosols and chemically reactive gases with short atmospheric lifetimes, ranging from a few hours to a couple of decades (Szopa et al., 2021). Due to their short atmospheric lifespan, reductions in SLCF emissions can slow warming quickly, within years to decades (Shindell et al., 2012; Szopa et al., 2021). Depending on the species, they can exert either a cooling or warming effect on the

climate. Some of the warming species, such as methane (CH_4), black carbon (BC), and hydrofluorocarbons (HFCs), have global warming potentials far higher than carbon dioxide (CO_2) per unit mass (Forster et al., 2021). Many SLCFs, or the secondary pollutants they form (such as tropospheric ozone and fine particulate matter), are also air pollutants with adverse effects on human health, ecosystems, and crop yields (UNEP & WMO, 2011; Shindell et al., 2012). The SLCFs covered in this study are CH_4, BC, HFCs, sulphur dioxide (SO_2), organic carbon (OC), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and carbon monoxide (CO) (see Annex A2).

Prior studies agree that SLCF mitigation is an important mitigation measure (e.g., Dreyfus et al., 2022; Harmsen et al., 2020). However, studies vary widely on how much it contributes to limiting warming. For example, estimates of the avoided warming in 2050 from targeted SLCF mitigation can range from around 0.16°C (Smith and Mizrahi, 2013) to 0.50°C (Shindell et al., 2012). Much of this spread arises from differences in scenario assumptions and experimental design. Crucially, because many are co-emitted alongside CO_2 in combustion processes, the temperature benefits of SLCF mitigation are highly sensitive to the level of ambition in decarbonisation in the scenario design and to whether the linkage between CO_2 and SLCF emissions is properly accounted for (Rogelj et al., 2014). This highlights the need for additional studies that carefully disentangle the relationship between CO_2 and combustion-linked SLCFs, and assesses how different levels of decarbonisation ambition impact the benefit of targeted SLCF mitigation.

Moreover, since these studies were published, global emissions have continued to rise and new research and mitigation pathways have become available. This study thus provides updated, quantitative evidence on how SLCF mitigation shapes temperature outcomes, drawing on the latest global emissions pathways from integrated assessment models. It assesses the role of targeted SLCF reductions in limiting overshoot, both independently and in comparison or combination with TAFF, LULUCFand novel CDR, quantifying how each lever, in isolation and in combination, reduces the rate of global warming, limits peak temperatures, and contributes to returning below 1.5°C before 2100.

3. Methodology

In this section, we provide an overview of the methods used to assess the four research questions covered by the analysis.

3.1. Lever Definition

This technical annex assesses four mitigation levers, plus a fifth "other measures" category that captures any remaining greenhouse gas emissions which are not covered by the four key levers.

1. **TAFF:** reduces fossil fuel production and use, cutting energy-related CO_2 emissions. It also leads to reductions in associated pollutants – CH_4 from the extraction, processing and distribution of fossil fuels, and air pollutants from their combustion, such as BC – which adds to the avoided warming by the CO_2 reductions. Our estimates of the climate benefits for TAFF include reductions in forcing agents (air pollutants) that have masked some of the warming effects of CO_2 emissions (sulphur dioxide, nitrogen oxides, organic carbon). The benefits of phasing out fossil fuels include substantial co-benefits, notably improved air quality from these emissions reductions.

2. **Targeted SLCF mitigation:** reduces SLCF emissions via targeted measures beyond TAFF. This includes addressing fugitive CH_4 emissions in fossil fuel extraction; cutting CH_4 from agriculture and waste; phasing down HFCs; and reducing other air pollutants that are not linked with fossil fuel combustion, such as industrial process emissions.

3. **LULUCF:** reduces emissions from deforestation and large-scale land burning. This cuts both CO_2 emissions and co-emitted SLCFs such as BC and OC. It also covers the growth in CDR from conventional methods such as afforestation and reforestation. The warming avoided per tonne of CO_2 reduced or removed is not constant: for land-based removals, higher warming raises the risk that sequestered carbon is later re-released through wildfire, drought, or ecosystem breakdown, reducing the effective permanence of each tonne removed. For emission reductions more broadly, carbon-cycle feedbacks and the risk of crossing tipping points make the warming response less predictable as temperatures rise. The climate model used in this study captures the gradual weakening of the land and ocean carbon sinks, but not abrupt tipping-point dynamics, ecosystem collapse, or the reversal of land-based carbon removals.

4. **Novel CDR:** removes CO_2 from the atmosphere for durable geological storage via engineered approaches such as bioenergy with carbon capture and storage (BECCS) and direct air capture with storage (DACCS).

5. **Other measures:** While these four levers are the focus of our analysis, and capture most of the mitigation options available to policymakers, they do not cover a subset of remaining actions, including reducing emissions of N_2O, CO_2 from industrial processes, and fluorinated gases other than HFCs (PFCs and SF_6). To capture these, we also produce a Deep Mitigation pathway which also sets these emissions to their highest possible ambition, in addition to the four key levers.

Table 3.1 Gases included in each of the four key mitigation levers.

Lever	Gases Included
TAFF	Energy-sector CO_2, CH_4, BC, CO, NO_x, OC, SO_2, VOC
Targeted SLCF mitigation	CH_4 (agriculture, waste, and energy intensity), HFCs, and BC, CO, NO_x, OC, SO_2, VOC from non-energy, non-land-use sources
LULUCF	Land-use CO_2, BC, CO, NO_x, OC, SO_2, VOC
CDR	Combined BECCS and DACCS

3.2. Data Sources

In this research we build a single harmonised dataset of global emissions pathways, spanning the range of mitigation ambition from Reference pathway projections through to Deep Mitigation pathways aligned with the Paris Agreement.

IAMs. Scenario pathways are drawn from an ensemble of the latest multi-model intercomparison projects, covering 29 models and 50 current-policy scenarios: ELEVATE (Hooijschuur et al., 2025), ScenarioMIP-CMIP7 (van Vuuren et al., 2026), and the Scenario Compass Initiative (SCI-2025 v1.0) (Riahi et al., 2026). Full dataset versions and citations are given in Annex A1.

Harmonisation. Every pathway is rescaled to match observed history at a 2023 anchor year, using the harmonisation tool aneris (Gidden et al., 2019), with the rescaling method chosen automatically by aneris per series based on trajectory shape: reduce_ratio_2080 scales to match history exactly at 2023 then decays back to the model's own trajectory by a target year; constant_ratio and constant_offset apply a fixed multiplicative or additive correction across all years; budget solves for a cumulative-total-matching trajectory; and hist_zero/model_zero pass through unchanged when either side is exactly zero at the anchor. Each gas is harmonised to the historical record given in Table A1.1. HFCs are the one exception: they are not harmonised. The HFC pathways are taken directly from Velders et al. (2022) as reported, so they are not reconciled to the EDGAR historical record at the 2023 anchor year.

Historical data. Historical emissions (1990–2023) for BC, SO_2, NO_x, VOCs, and OC come from the Community Emissions Data System (CEDS; Hoesly et al., 2025), combined with BB4CMIP7 (Biomass Burning for CMIP7; ., open biomass burning emissions for CMIP7), a global biomass-burning dataset covering the fire component of these pollutants. CH_4 and CO_2 historical emissions come from CMIP7-fastmip's own historical compilation (Smith, 2026). HFCs' historical record comes from EDGAR (Emissions Database for Global Atmospheric Research; Crippa et al., 2025). Full dataset versions, citations, and per-gas coverage are given in the Scenario Databases table (Annex A1).

3.3. Building self-consistent emissions pathways

When constructing scenarios, it is important to capture the interrelationships between gases. Many gases share the same underlying drivers (e.g. combustion of fossil fuels), and a self-consistent emissions pathway should capture these interrelationships.

Pathways not percentiles

Where this annex gives a percentile, it means the single IAM pathway closest to that percentile by RMSE, not a value computed across the ensemble at each timestep. We do this so every gas in a scenario comes from a real, internally consistent model run. Percentiles are taken in two ways: for co-emitted gases, from the spread of pathways around the lead CO_2 pathway, where a higher percentile means more co-emitted gases per unit of CO_2; for non-co-emitted gases, from the IAM ensemble directly, where a lower percentile means lower emissions. Table 3.2 gives the percentile used for each gas in each pathway.

Co-emitted gases

We focus on two key areas of co-emissions, both of which are related to combustion emissions.

First, fossil fuel combustion produces CO_2 emissions. It also results in co-emissions of BC, sulphur, NO_x, VOCs, OC and CO from incomplete fossil fuel combustion. In addition, the extraction and processing of fossil fuels leads to emissions of energy-sector methane. Secondly, when forests, croplands and grasstlands are burned, this releases CO_2 emissions which are accounted for in the LULUCF sector. However, it also results in co-emissions of BC, sulphur, NO_x, VOCs, OC and CO.

For these gases, we build a link between combustion-related CO_2 emissions and co-emitted gases as follows.

1. We treat CO_2 as the lead gas in this analysis and select a CO_2 pathway that best aligns with the scenario of interest (whether the Reference, Intermediate Ambition or Deep Mitigation pathway).

2. We then identify a range of future emissions for all the co-emitted gases that are still consistent with the lead gas emissions pathway (CO_2). We do this by finding the 10 pathways which are closest to this lead CO_2 emissions pathway (via RMSE) and then extracting their future emissions for the co-emitted gases. This allows us to construct an uncertainty range for the co-emitted gases. This range shows how a single level of CO_2 emissions can be associated with a wide range of different possible outcomes for co-emitted gases. This spread largely captures varying levels of actions to curb air pollutants from combustion, such as flue-gas desulphurisation to reduce sulphur emissions from coal-fired power plants.
3. We select a pathway from within this uncertainty range. This spread allows us to vary our assumptions around how strong air pollutant controls are assumed to be in the future – taking a higher quantile from this spread represents a world in which there is less action to control air pollutants, and hence the level of co-emitted gases per unit of CO_2 is higher. Taking a lower quantile captures more of the progress made to de-link CO_2 emissions and some of these downstream combustion gases by air pollution measures.

We use this method to select all co-emitted gases. Each scenario therefore involves two choices: which CO_2 pathway to use as the lead gas, and which percentile of the associated co-emissions spread to take. The Reference, Deep Mitigation and IAS pathways (Section 3.4) take the median of the spread; the Policy-failure pathway takes the 75th percentile, representing weaker control measures for co-emitted gases.

Non-co-emitted gases

While some gases are co-emitted with CO_2, many are not. In particular, methane from agriculture and waste, HFCs, and emissions from industrial processes/waste have no clear physical link to CO_2 combustion. In these cases, we construct scenarios from the ensemble of IAMs without considering the relationship with other gases.

3.4. Pathway Construction

This section describes four pathways used in this analysis. Two are core pathways: a Reference pathway representing ongoing delivery of current policies, and a Deep Mitigation pathway representing the highest possible ambition across all levers. Two are sensitivity pathways: an Intermediate Ambition Scenario (IAS), in which TAFF proceeds more slowly, and a Policy-failure pathway reflecting weaker, incomplete future delivery of existing policies. All four are described below and summarised in Table 3.2. Figure 3.1, Figure 3.2, and Figure 3.3 show how each pathway is constructed gas by gas, for the Energy, LULUCF, and Other sectors respectively. "Other" here means sources that are neither energy nor land use: CH_4 from agriculture and waste, HFCs and non-fossil air pollutants, which make up the targeted SLCF lever, plus the N_2O, industrial-process CO_2 and other F-gas residuals, which move only in Deep Mitigation.

Reference pathway (Core): The Reference pathway is a current-policy scenario, representing emissions if existing policies continue as planned. This is used as the baseline for analysis. The pathway is constructed as follows:

- CO_2 emissions (both energy and AFOLU) – the IAM pathway that matches the Climate Action Tracker's (CAT) own estimate of the CO_2 emissions under current policies is chosen.
- Co-emitted gases – selected according to the co-emissions methodology described above, using the median of the co-emissions spread.
- Non-co-emitted gases – the median of current-policy IAM ensemble is used in all cases except HFCs. For HFCs, we use the mean of the Kigali Amendment (KA-2022) lower and upper bounds from Velders et al. (2022), which captures implementation of the Kigali Amendment.

Deep Mitigation pathway (Core): This pathway captures the impact of pursuing mitigation in each individual lever (TAFF, SLCF, LULUCF, CDR and Other) in a manner which aligns with highest possible ambition. We construct this pathway as follows:

- CO_2 emissions (both energy and AFOLU) – we take directly the REMIND HPA-2025 analysis.
- Co-emitted gases – selected according to the co-emissions methodology described above, using the median of the co-emissions spread.
- For non co-emitted gases, we use the 25th percentile of the 1.5°C-aligned IAM ensemble, except for methane from agriculture and waste. In this case, we select pathways which explicitly meet the Global Methane Pledge.

Intermediate Ambition Scenario (IAS) pathway (Sensitivity): The IAS tests temperature outcomes in a world where TAFF is delayed, and how much larger the benefit of targeted SLCF action becomes when TAFF ambition is lower than the Deep Mitigation pathway. It is a modified form of the Deep Mitigation pathway, constructed as follows:

- Re-anchored gases – energy-sector CO_2, CDR, energy-sector CH_4, and the six energy-sector air pollutants (BC, CO, NO_x, OC, SO_2, VOC) are re-anchored to a different 1.5°C pathway (WITCH 6.0, "Low-to-Negative - SSP1") than Deep Mitigation's NPE-Core.
- Anchor selection – the new anchor is chosen from eligible Paris-aligned pathways that report both CO_2|Energy and CH_4|Energy and a Gross CO_2/CDR split, have higher 2023–2050 cumulative emissions than NPE-core on both gases, and sit nearest the eligible pool's 90th percentile.
- All other gases – AFOLU, HFCs, nitrous oxide, and the residual waste/industrial rows carry Deep Mitigation's values unchanged.

Policy-failure pathway (Sensitivity): The Policy-failure pathway is also constructed to explore the role of SLCFs, TAFF, LULUCF and CDR in a world with weaker, incomplete

future delivery of existing policies. The pathway is constructed in the same way as the Reference pathway, with the following minor changes:

- Energy sector CO_2 emissions are selected to match the CAT's high estimate of current policies.
- Co-emitted gases use the 75th percentile of the co-emissions spread.
- Agriculture and waste CH_4 instead use bottom-up estimates of how their emissions will evolve in future, drawn from the GAINS model (Höglund-Isaksson et al., 2020). These are more pessimistic than the assumptions from current policy scenarios from IAMs.
- HFCs instead use the lower bound of the Current Policy (KI-2022) scenario from Velders et al. (2022), which does not assume Kigali Amendment compliance.

Energy-sector CH_4 decomposition: Energy-sector CH_4 is decomposed into an activity component (how much fossil fuel is produced) and an intensity component (CH_4 released per unit produced). This separates the methane reductions that follow automatically from fossil phase-out from those requiring targeted abatement, and underpins the CH_4 energy-intensity sub-lever reported in Section 4.

Table 3.2 Scenario construction by gas and scenario

Gas family	Reference Pathway	Deep Mitigation Pathway	IAS Pathway	Policy-failure Pathway
CO_2 (Energy)	Closest real pathway to CAT-GA's CPP_low	REMIND-HPA (NPE-core), direct	Re-anchored to WITCH 6.0 "Low-to-Negative - SSP1"	Closest real pathway to CAT-GA's CPP_high
CO_2 (AFOLU)	Closest real pathway to CAT-GA's land-use target	REMIND-HPA (NPE-core), direct	Carries Deep Mitigation unchanged	Closest real pathway to CAT-GA's land-use target
CH_4 (Energy)	Co-emissions method, median of the co-emissions spread	REMIND-HPA (NPE-core), direct	Co-emissions method, median of the co-emissions spread	Co-emissions method, 75th percentile of the co-emissions spread
BC/SO_2/NO_x/VOC/CO (Energy, AFOLU)	Co-emissions method, median of the co-emissions spread	Co-emissions method, median of the co-emissions spread	Co-emissions method, median of the co-emissions spread	Co-emissions method, 75th percentile of the co-emissions spread

CH_4 (Agriculture, Waste)	Median of current policy scenarios	Hand-picked pathway meeting the Global Methane Pledge (IMAGE 3.2 for Waste; MESSAGEix-GLOBIOM 2.0 for AFOLU)	Carries Deep Mitigation unchanged	GAINS bottom-up model
HFC	Velders et al. (2022) – Kigali Amendment scenario	25th percentile of the 1.5°C pool, or REMIND-HPA (NPE-core), direct, if more ambitious	Carries Deep Mitigation unchanged	Velders et al. (2022), Current policy estimate
N_2O, PFC, SF_6, Industrial/Waste residuals	Median of current policy scenarios	25th percentile of the 1.5°C pool, or REMIND-HPA (NPE-core), direct, if more ambitious	Carries Deep Mitigation unchanged	Median of current policy scenarios

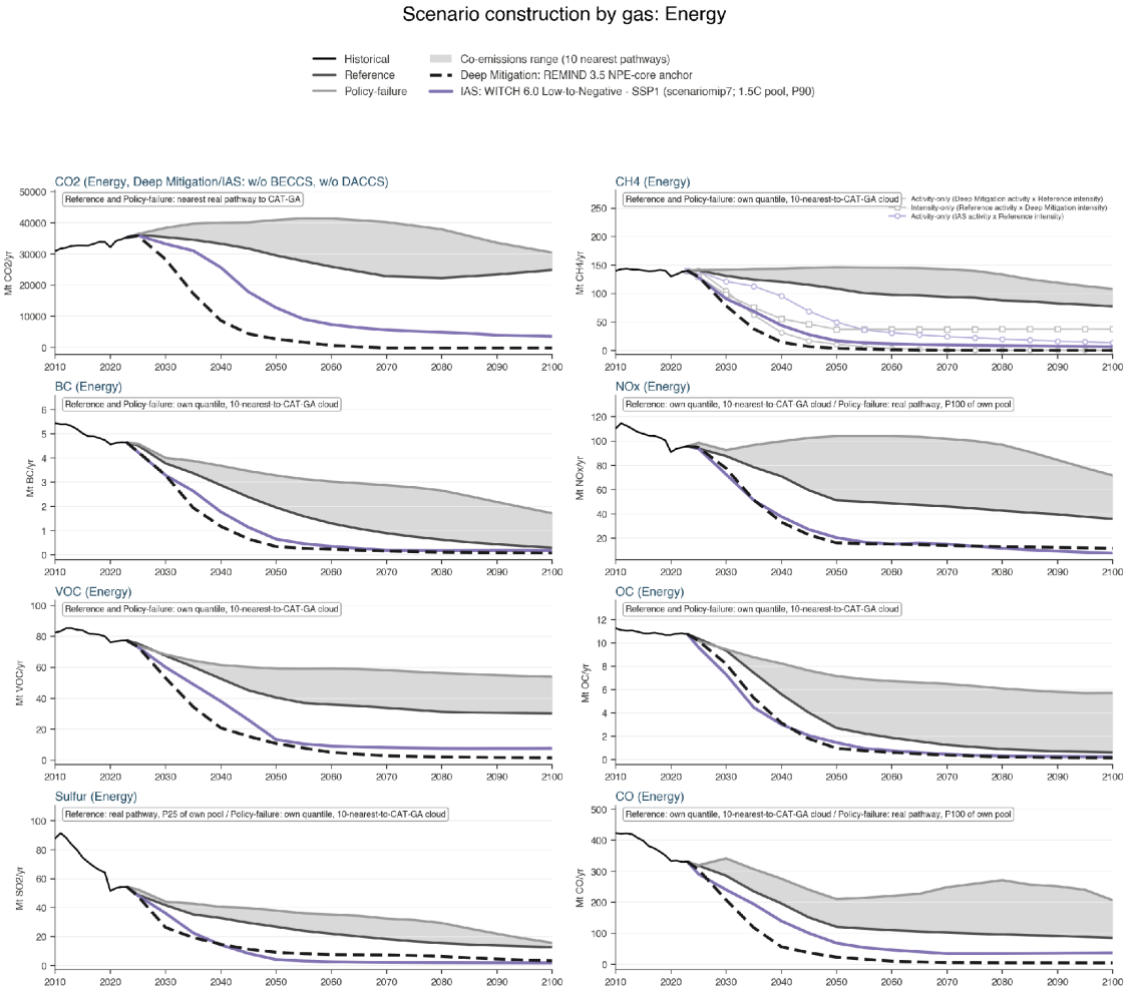


Figure 3.1 Scenario construction by gas: Energy. Energy-sector emissions for each gas under the Reference, Policy-failure, Deep Mitigation and IAS pathways, 2010–2100. Black lines are historical emissions. The shaded band spans the co-emissions of the 10 IAM pathways nearest the lead CO_2 pathway: the Reference pathway takes the median of this band, the Policy-failure pathway the 75th percentile (Section 3.3). Deep Mitigation follows REMIND 3.5 NPE-core directly; IAS re-anchors the fossil-linked gases to WITCH 6.0 Low-to-Negative SSP1, so it separates from Deep Mitigation in these panels. The box on each panel gives the selection rule applied to that gas, as summarised in Table 3.2. The CH_4 panel additionally shows the activity-only and intensity-only decompositions described in Section 3.4.

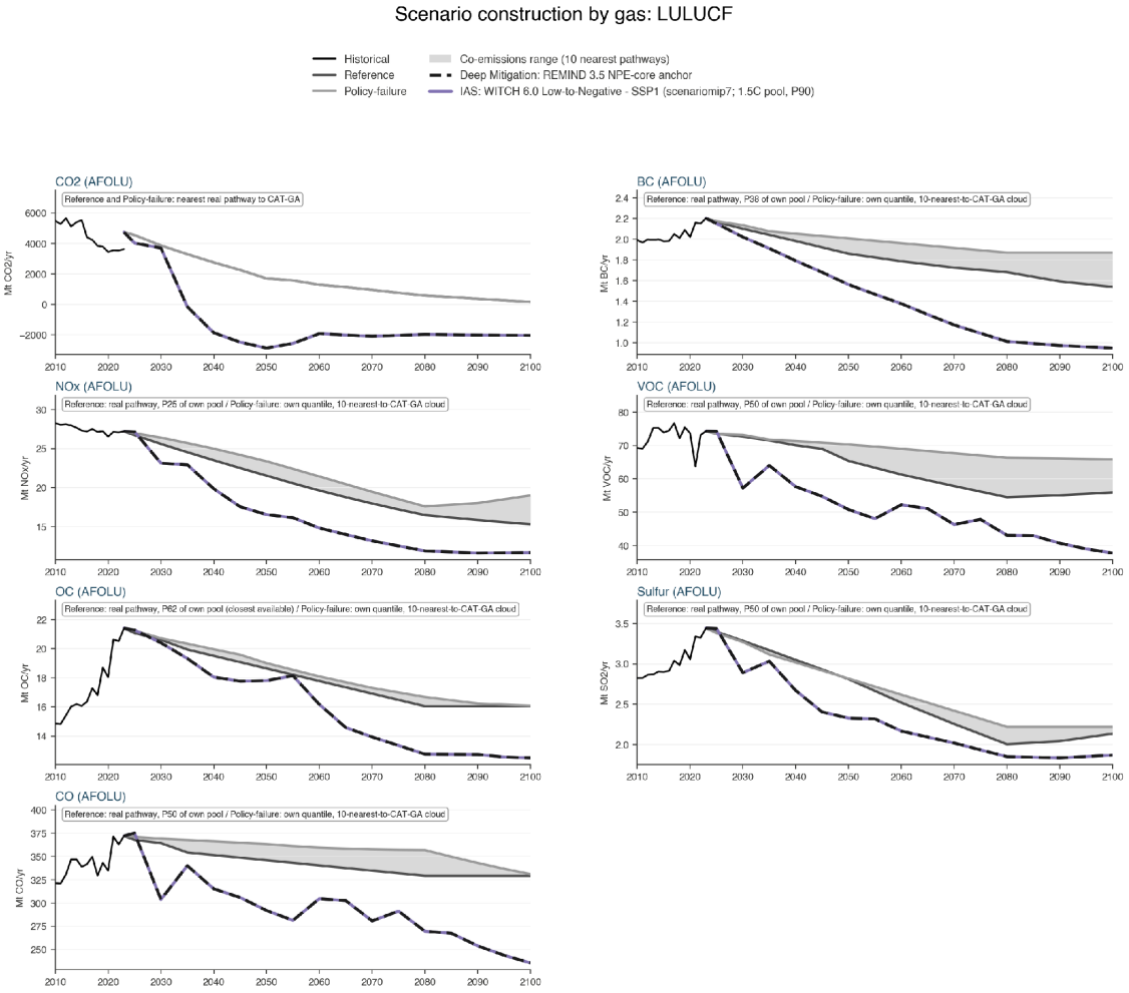


Figure 3.2 Scenario construction by gas: LULUCF. Land-use sector emissions for each gas under the Reference, Policy-failure, Deep Mitigation and IAS pathways, 2010–2100. Black lines are historical emissions. The shaded band spans the co-emissions of the 10 IAM pathways nearest the lead CO_2 pathway: the Reference pathway takes the median of this band, the Policy-failure pathway the 75th percentile (Section 3.3). The LULUCF lever is not re-anchored in IAS, so the IAS line sits underneath Deep Mitigation in every panel. The box on each panel gives the selection rule applied to that gas, as summarised in Table 3.2. CO_2 (AFOLU) turns net-negative from around 2040 under Deep Mitigation as afforestation and reforestation scale up.

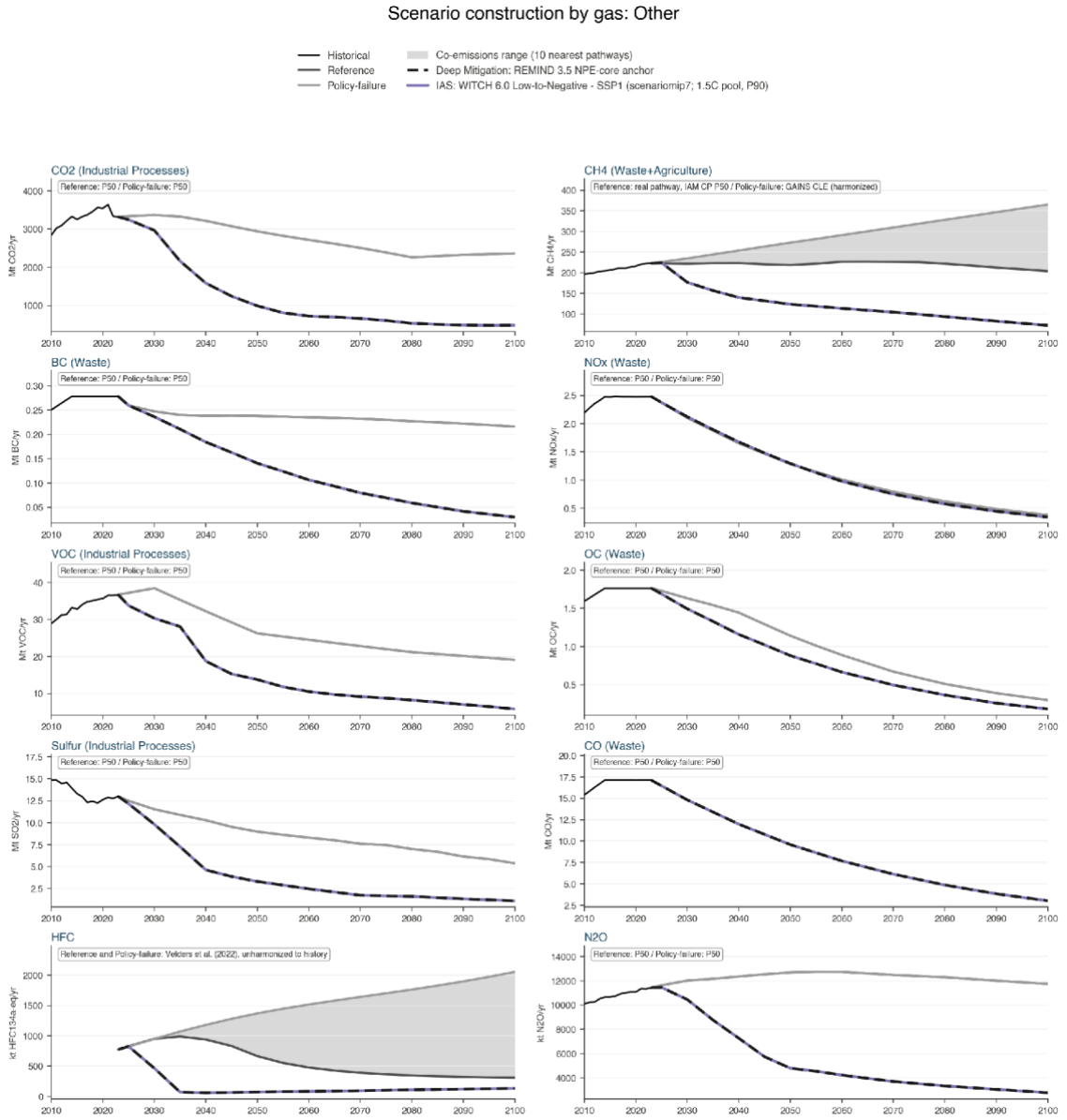


Figure 3.3 Scenario construction by gas: Other (Targeted SLCFs). Emissions of the non-fossil, non-land-use gases under the Reference, Policy-failure, Deep Mitigation and IAS pathways, 2010–2100: CH_4 from waste and agriculture, HFCs, N_2O, and industrial-process and waste air pollutants. Black lines are historical emissions. These gases are not re-anchored in IAS, so the IAS line sits underneath Deep Mitigation in every panel. The box on each panel gives the selection rule applied to that gas, as summarised in Table 3.2. Two gases use bespoke sources rather than an ensemble percentile: CH_4 (waste and agriculture) takes the IAM current-policy median in the Reference pathway and the GAINS current-legislation (CLE) projection in the Policy-failure pathway, and HFCs come from Velders et al. (2022) and are the one gas not harmonised to history (Section 3.2).

3.5. Scenario Design

Once the Reference, Deep Mitigation, and IAS pathways are constructed, scenarios then isolate and combine the four mitigation levers across these pathways to quantify

each lever's individual and combined temperature effect. A scenario is built by selecting, gas by gas, which pathway's trajectory to draw from. Isolating a single lever means switching only that lever's gases (Table 3.1) to one of the three pathways; combining levers means switching more than one lever's gases at once. The Reference scenario draws every gas from the Reference pathway; the Deep Mitigation scenario draws every gas from the Deep Mitigation pathway. Scenarios built against the IAS pathway show how the benefit of targeted SLCF action depends on the level of TAFF ambition.

A scenario is built by selecting, gas by gas, which pathway's trajectory to draw from (see Table 3.1 in Lever Definition for the gas-to-lever mapping).

The full scenario list, with IDs and precise definitions, plus how each bucket maps to the research questions, is provided in Annex A3.

3.6. Temperature Assessment

Global mean surface temperature (GMST) was simulated using the reduced-complexity climate model MAGICCv7.5.3 (Meinshausen et al., 2020), run through the AR6 climate-assessment workflow (Kikstra et al., 2022)[1]. We used the 600-member probabilistic parameter set calibrated to the IPCC AR6 WGI assessment of Earth's energy budget, climate feedbacks and climate sensitivity (Forster et al., 2021). Volcanic forcing was switched off in all simulations.

MAGICC requires HFC emissions by individual species rather than a single aggregate basket. The Reference and Policy-failure pathways (Velders et al., 2022) already report species-level HFC emissions; the mitigation pathways (Deep Mitigation and IAS) report only an aggregate basket, which we split into species using climate-assessment's infilling module, run from each scenario's energy-sector CO_2 trajectory and rescaled so their AR6 GWP100-weighted sum matches the original basket. This ensures the same seven HFC species (HFC-23, -32, -125, -134a, -143a, -227ea, -43-10mee) are present in every scenario.

[1] Emulator configuration and its limitations. Global temperature outcomes were computed with MAGICC v7.5.3 using the IPCC AR6 WGIII probabilistic calibration (600 configurations; Kikstra et al., 2022), while the emissions inputs are harmonised to 2023 using CMIP7-era historical emissions. This analysis is therefore a partial update: the future emissions pathways reflect current data, but the historical emissions, model version and calibration have not yet been updated to match, and will be in future studies. To gauge the effect of this inconsistency, we reran the six core Reference-pathway scenarios through the CMIP7 climate-assessment workflow (CMIP7 harmonisation and infilling, CMIP7 historical emissions for 2015–2022, and MAGICC v7.6 with the AR7 fast-track calibration). The avoided warming attributed to each lever changed by no more than around 0.01°C at 2050, 2100 and peak warming, and the ranking of levers was unchanged.

3.7. Limitations and uncertainty

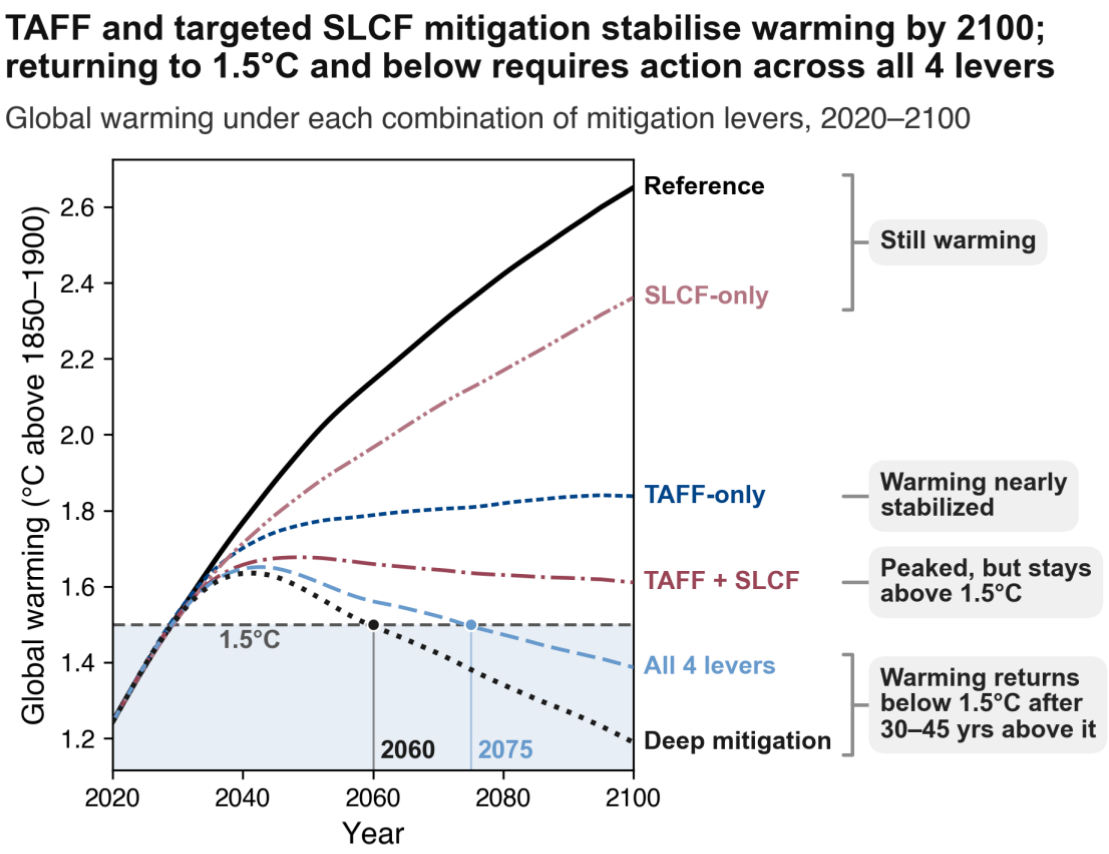
- **Scenario design choices shape the results:** the choice of baseline (Reference vs Policy-failure) and of the mitigation pathways (Deep Mitigation's and IAS's own construction rules) materially affects every result in this technical annex.
- **Composite pathway construction:** Our pathways are built gas by gas, drawing on different IAMs for different gases, rather than following one internally consistent model scenario across every gas. Cross-gas relationships a single model would preserve internally are thus not guaranteed here.
- **Model diversity varies by gas:** Some highest-ambition picks (NO_x, VOC, and CO in the energy sector) are drawn from a pool that narrows to only two or three models once the ambition filter is applied, so those specific trajectories reflect fewer independent models than the headline dataset counts suggest.
- **Some gases are only captured within Deep Mitigation, not as a standalone lever:** N_2O, PFCs, SF_6, and industrial-process CO_2 move to highest ambition only in the Deep Mitigation pathway (see Lever Definition), so their combined effect shows up in the gap between "All 4 levers" and "Deep Mitigation," but isn't decomposed into an individual contribution like TAFF, SLCF, LULUCF, and CDR are.

4. Results

4.1. Core Scenarios

4.1.1. Summary of results presented in the policy brief

The Core Scenarios are the two pathways the policy brief's results are built on: the Reference pathway, representing ongoing delivery of current policies, and Deep Mitigation, representing the highest possible ambition across all four levers plus other measures. Under the Reference pathway, GMST continues rising throughout the 21st century, reaching approximately 2.7°C above pre-industrial levels by 2100 (Figure 4.1). With targeted SLCF mitigation, end-of-century warming decreases to around 2.4°C, while under TAFF, warming falls to around 1.8°C. However, neither is sufficient to bring warming back below 1.5°C within this century. Combining the two levers brings end of century warming to around 1.6°C. Adding LULUCF and novel CDR brings 2100 warming to below 1.5°C, around 1.4°C. Reductions in mitigation measures beyond the four key levers in the Deep Mitigation pathway reduce warming further, to around 1.2°C by 2100, well below 1.5°C (Table 4.1). See the accompanying briefing for a detailed discussion of each lever's individual and combined contribution.



	Peak warming (°C)	Peak year	2100 (°C)
Reference	–	after 2100	2.7
SLCF-only	–	after 2100	2.4
TAFF-only	1.8	2095	1.8
TAFF + SLCF	1.7	2049	1.6
All 4 levers	1.7	2043	1.4
Deep mitigation	1.6	2041	1.2

Figure 4.1 GMST (relative to 1850–1900) under the Reference pathway and successively more ambitious scenarios: SLCF-only, TAFF-only, TAFF + SLCF, all four levers, and Deep Mitigation. MAGICC v7.5.3 ensemble medians.

Table 4.1 Lever contributions to avoided warming, Reference pathway. Avoided warming is the reduction in global mean surface temperature relative to the Reference pathway in that year.

Lever / scenario	Avoided warming 2050	Avoided warming 2100
TAFF	0.21°C	0.82°C
Targeted SLCF mitigation	0.12°C	0.29°C
TAFF + targeted SLCF	0.31°C	1.0°C

TAFF + SLCF + LULUCF + CDR	0.35°C	1.3°C
Deep Mitigation	0.39°C	1.5°C

4.1.2. Aerosol unmasking

TAFF delivers the largest avoided warming of any single lever by 2100, but that benefit takes decades to build. Early on, part of it is cancelled out by aerosol unmasking: cutting fossil fuel use also removes the cooling aerosols released alongside it. Aerosol unmasking is a well-documented short-term consequence of rapid decarbonisation: reflective aerosols decline alongside CO_2 and co-emitted SLCFs faster than the underlying CO_2 cuts' warming benefit accrues, producing a temporary net warming before the long-term benefit dominates. This section quantifies that effect and how it differs across levers.

As fossil fuel phase-out cuts co-emitted sulphate aerosols, the loss of their cooling effect temporarily adds warming relative to the Reference pathway (Figure 4.2). The effect is largest and longest under TAFF-only, peaking at 0.018°C in 2029 and keeping warming above the Reference pathway for eight years, 2026 to 2033, before crossing back below it in 2034. Targeted SLCF mitigation shows no equivalent effect, since it does not cut the same cooling aerosols at scale. Pairing the two therefore offsets part of the unmasking: under TAFF + SLCF the peak falls to 0.014°C and the period above the Reference pathway shortens to six years, 2026 to 2031, crossing back below in 2032. This is a further argument for pursuing the two together rather than TAFF alone.

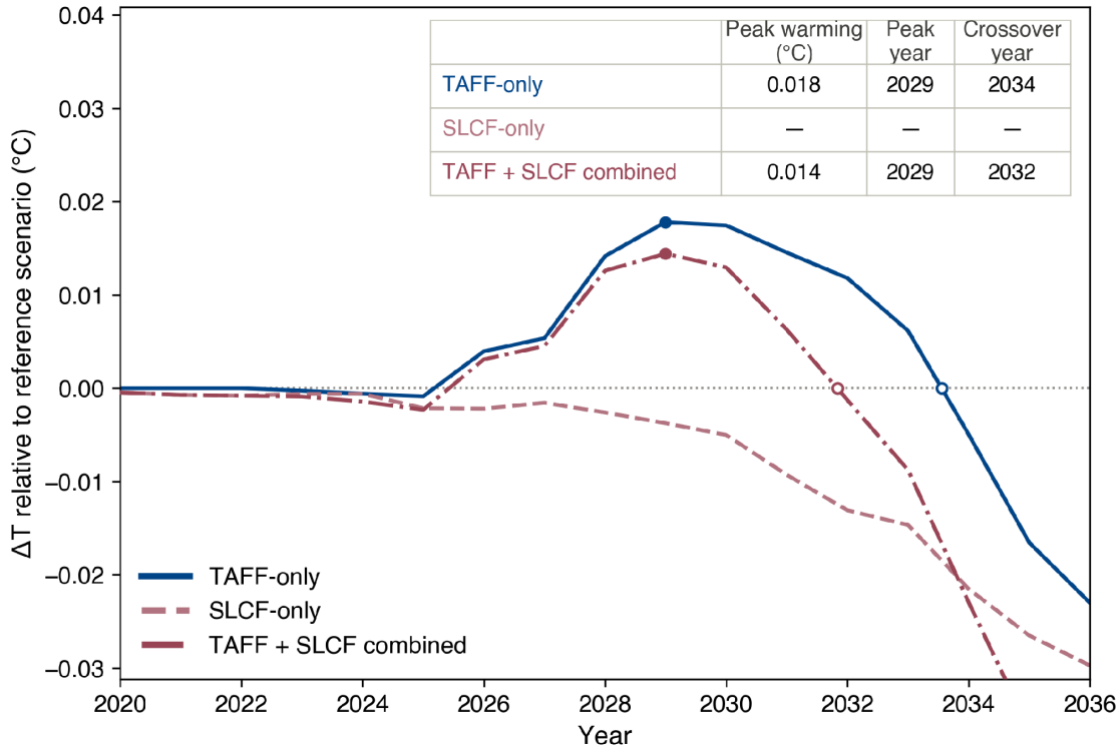


Figure 4.2 Short-term warming from aerosol unmasking under TAFF-only, SLCF-only, and TAFF + SLCF, relative to the Reference pathway, 2020–2036. TAFF temporarily adds warming relative to the Reference pathway as fossil fuel phase-out removes cooling sulfate aerosols — peaking at 0.018°C in 2029 before fading and crossing back below the Reference pathway by 2034 (2032 combined with targeted SLCF mitigation). SLCF-only shows no equivalent unmasking effect. Reference pathway. MAGICC v7.5.3 ensemble medians.

4.2. Sensitivity Analysis

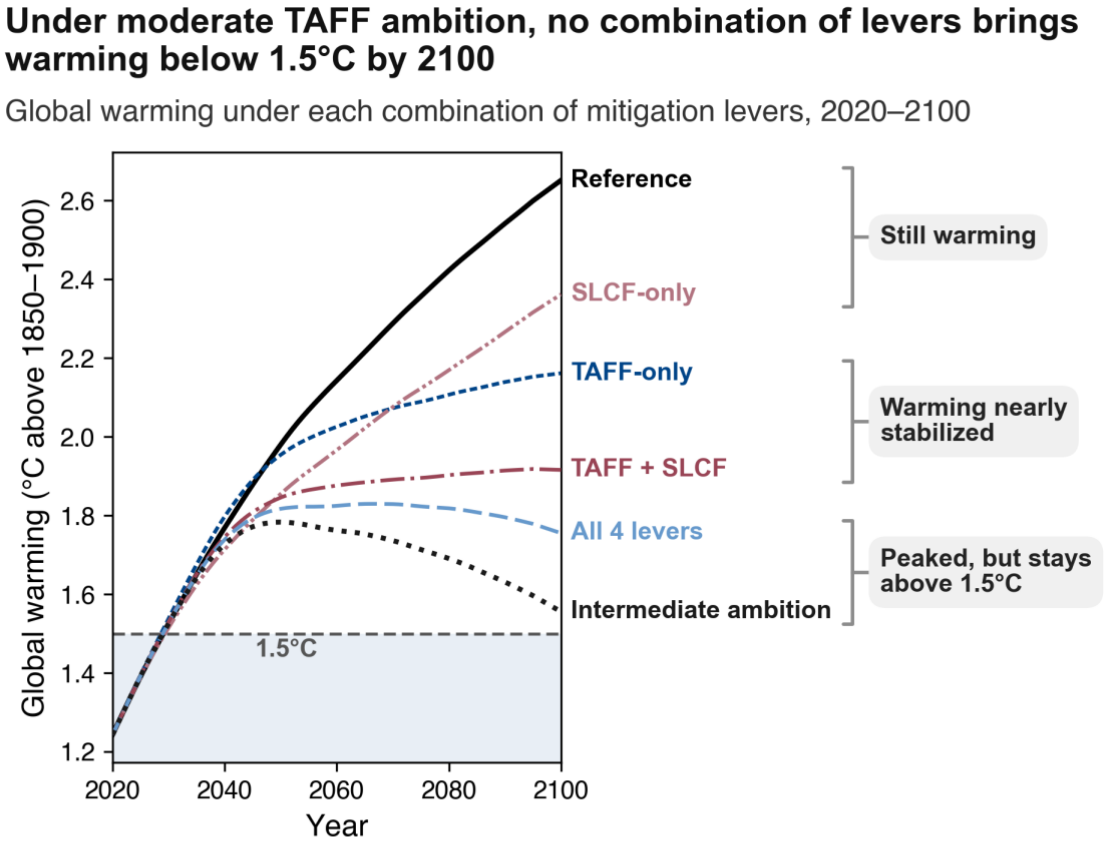
This section tests how the Core Scenario findings depend on two assumptions. The intermediate TAFF sensitivity below tests how the benefits of targeted SLCF mitigation change when TAFF is pursued at a lower level of ambition rather than its highest possible ambition. The Policy-failure pathway tests how results change under weaker, incomplete future policy delivery, compared to the Reference pathway used in the Core Scenarios. Together, these show how robust the Core Scenario findings are to these two key assumptions.

4.2.1. Intermediate TAFF ambition sensitivity

This section presents a sensitivity analysis in which TAFF is delayed rather than pursued at the highest possible ambition: the IAS pathway. No combination of levers returns warming below 1.5°C under the IAS pathway (Figure 4.3): even with all four levers

combined, warming reaches approximately 1.8°C by 2100, compared to 1.4°C when TAFF itself is pursued at its highest possible ambition. Delaying TAFF increases the relative importance of targeted SLCF mitigation, even as it reduces the total benefit available from any combination of levers. When fossil fuel phase-out is delayed, targeted SLCF mitigation accounts for a larger share of avoided warming. But this greater relative contribution does not compensate for the additional warming caused by slower CO_2 reductions. The strongest temperature outcomes depend on pursuing both measures together.

Only TAFF's ambition changes in this sensitivity. The gases tied to fossil fuel use are re-anchored to the slower pathway: energy-sector CO_2, energy-sector CH_4, the six energy-sector air pollutants, and novel CDR. Everything else is held at Deep Mitigation ambition, including CH_4 from agriculture and waste, HFCs, land-use emissions and the residual industrial gases. Every difference between this section and the Core Scenarios therefore originates in the energy sector.



	Peak warming (°C)	Peak year	2100 (°C)
Reference	–	after 2100	2.7
SLCF-only	–	after 2100	2.4
TAFF-only	–	after 2100	2.2
TAFF + SLCF	1.9	2095	1.9
All 4 levers	1.8	2067	1.8
Intermediate ambition	1.8	2050	1.6

Figure 4.3 GMST (relative to 1850–1900) under the Reference pathway and successively more ambitious scenarios built on the Intermediate Ambition Scenario (IAS): SLCF-only, TAFF-only, TAFF + SLCF, all four levers, and Intermediate Ambition (all levers + other measures). MAGICC v7.5.3 ensemble medians.

Under the IAS pathway, a delayed TAFF delivers no near-term warming rate reduction. TAFF alone leaves the warming rate slightly above the Reference pathway both in immediate near-term and in the 2030s: 0.27°C/decade against 0.25°C/decade over 2026–2035, and 0.28°C/decade against 0.26°C/decade over 2031–2040 (Figure 4.4). Targeted SLCF mitigation alone still slows warming in both, to 0.22°C/decade (11% below the Reference pathway) and 0.21°C/decade (18% below). Combining the two gives 0.25 and 0.23°C/decade, far short of the halving to 0.13°C/decade achieved over the 2030s when TAFF is pursued at its highest possible ambition.

Aerosol unmasking is why TAFF alone runs above the Reference pathway here in the near-term. Delaying the transition makes the unmasking both larger and much longer-lasting: its peak rises from 0.018°C in 2029 to 0.033°C in 2038, and the period during which TAFF keeps warming above the Reference pathway stretches from eight years to 27, with the crossover slipping from 2034 to 2048. Pairing TAFF with targeted SLCF mitigation offsets much of this, cutting the peak to 0.010°C and the duration to 11 years.

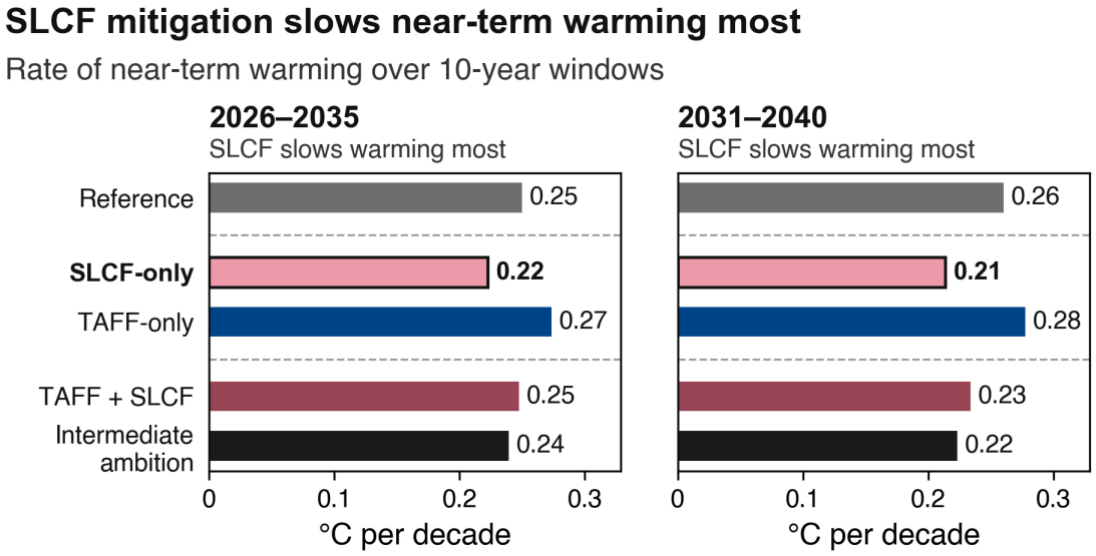


Figure 4.4 Rate of near-term warming over 2026–2035 (left panel) and 2031–2040 (right panel) by lever under the Reference pathway. The mitigation pathways are the isolated levers (TAFF-only and SLCF-only); combined TAFF and SLCF (TAFF + SLCF); and Intermediate Ambition (all levers + other measures). The vertical grey line shows the recent historical warming rate (2021–2025). All values are MAGICC v7.5.3 ensemble medians.

In 2050, targeted SLCF mitigation alone avoids 0.12°C, relative to the reference case. Since the total achievable warming in the IAS scenario is smaller than in the deep mitigation scenario when TAFF is pursued at the highest possible ambition, the share of avoided warming from SLCF cuts rises from 32% to 64%. Under the IAS, where TAFF is delayed, TAFF's total avoided warming declines from 0.21°C in the high ambition scenario to just 0.023°C (Figure 4.5). Almost all of the mid-century benefit of combining TAFF with targeted SLCF mitigation under the IAS pathway therefore comes from targeted SLCF mitigation rather than from fossil decarbonization, because TAFF's contribution has shrunk.

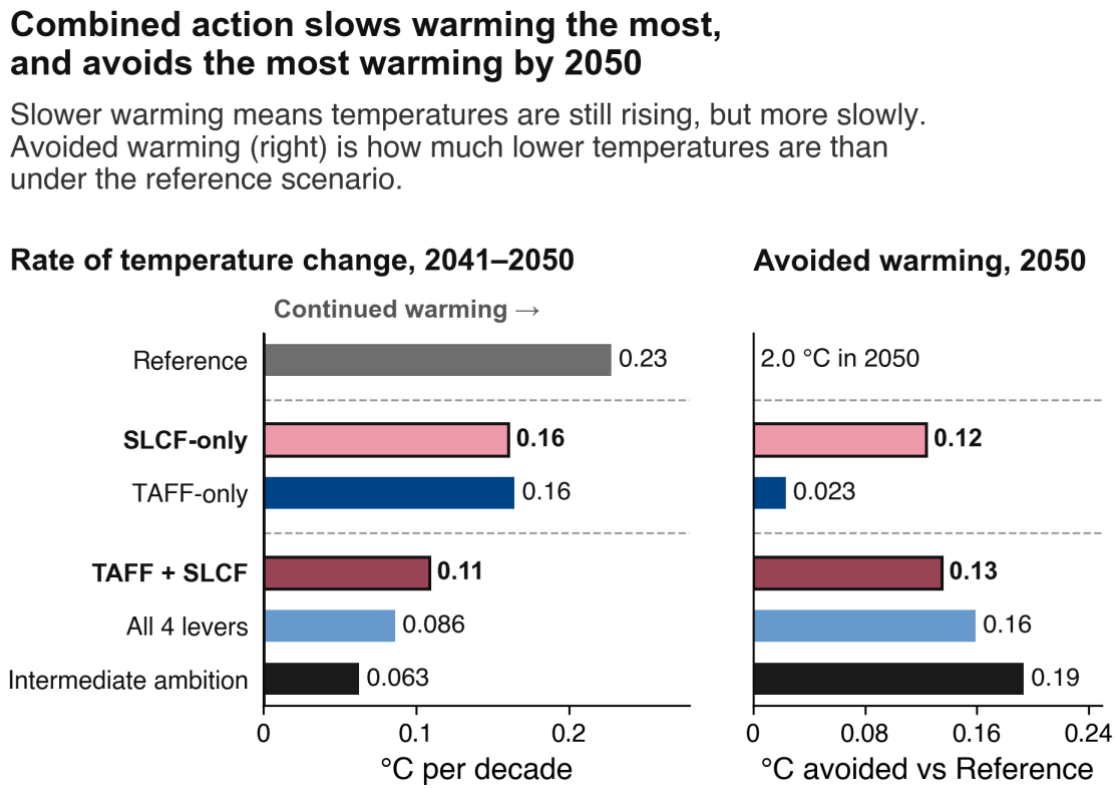


Figure 4.5 Rate of temperature change over 2041–2050 (left) and avoided warming relative to the Reference pathway in 2050 (right) under individual and combined mitigation levers, Intermediate Ambition Scenario (IAS). The mitigation pathways are the isolated levers (SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); all four levers (TAFF, SLCF, CDR and LULUCF) combined; and Intermediate Ambition (all levers + other measures). Negative rates indicate cooling. All values are MAGICC v7.5.3 ensemble medians.

The same pattern holds in 2100. Delaying TAFF cuts TAFF's own avoided warming from 0.82°C to 0.49°C and novel CDR's from 0.17°C to 0.11°C. CDR shifts because its pathway is derived from the same lead-gas scenario as energy-sector CO_2, so a slower fossil transition carries the CDR trajectory with it. Targeted SLCF mitigation (0.29°C) and LULUCF (0.061°C) are identical in both cases, since neither lever's ambition has changed (Figure 4.6, with Table 4.1 for comparison). The total end-of-century avoided warming available from the most ambitious combination falls from around 1.5°C to 1.1°C. While on its own, targeted SLCF mitigation's contribution is unchanged, at 0.29°C in 2100, its share of the total rises from 20% to 26%, since the total avoided warming is now smaller.

Delaying TAFF has a larger impact on temperature outcomes in mid-century than end of century. The total avoided warming between the Reference pathway and Deep Mitigation falls from 0.39°C to 0.19°C in 2050 (roughly half) but only from 1.5°C to 1.1°C in 2100 (around a quarter). The transition still happens, just later, so by 2100 the slower pathway has largely caught up: TAFF-only avoided warming falls from 0.82°C to

0.49°C. At 2050 almost none of TAFF's benefit has arrived yet, and its avoided warming falls from 0.21°C to 0.023°C.

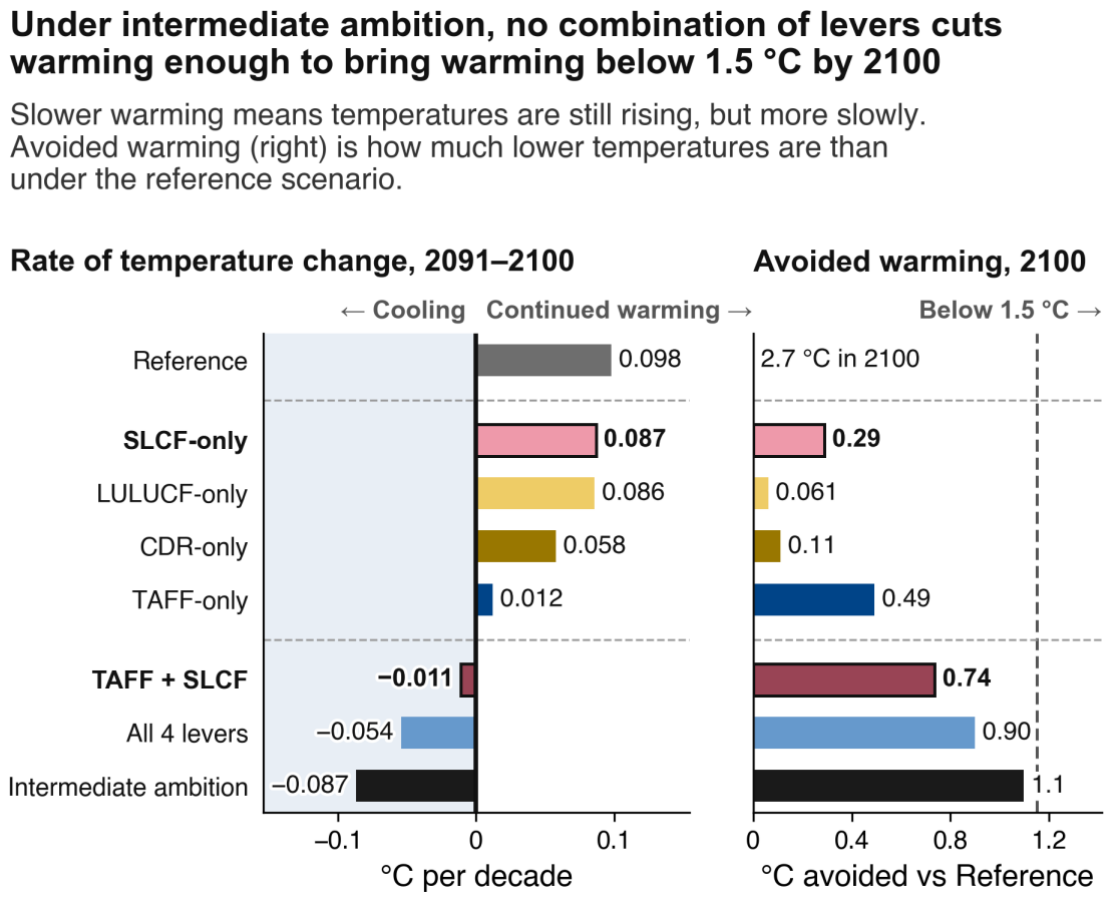


Figure 4.6 Rate of temperature change over 2091–2100 (left) and avoided warming relative to the Reference pathway in 2100 (right) under individual and combined mitigation levers, Intermediate Ambition Scenario (IAS). The mitigation pathways are the isolated levers (LULUCF-only, CDR-only, SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); all four levers (TAFF, SLCF, CDR and LULUCF) combined; and Intermediate Ambition (all levers + other measures). Negative rates indicate cooling. All values are MAGICC v7.5.3 ensemble medians.

The additional contribution of targeted SLCF mitigation on top of TAFF differs between the Reference Case and the IAS. Almost all of this difference comes from energy-sector CH_4. When TAFF is delayed, the CH_4 energy-intensity lever avoids 0.040°C in 2050 and 0.028°C in 2100, against 0.018°C and 0.005°C when TAFF is pursued at its highest possible ambition, because a slower phase-out leaves fossil CH_4 in place for targeted abatement to reduce. This finding is illustrated in Figure 6 of the policy brief.

Within targeted SLCF mitigation, only the energy-intensity lever responds to TAFF ambition. The agriculture, waste, and HFC sub-levers are unchanged from the Core Scenarios because none of them are re-anchored. In the IAS, the energy-intensity lever delivers a similar temperature benefit as reductions in agricultural methane in 2050

(0.040°C compared to 0.042°C), where under full TAFF ambition it delivers less than half as much. Reductions in agricultural methane still deliver the largest single benefit in 2100 (0.14°C), followed by waste (0.082°C). Mitigation of other SLCFs still adds a small amount of warming in both 2050 and 2100 as co-emitted cooling aerosols are removed alongside the warming agents (Figure 4.7).

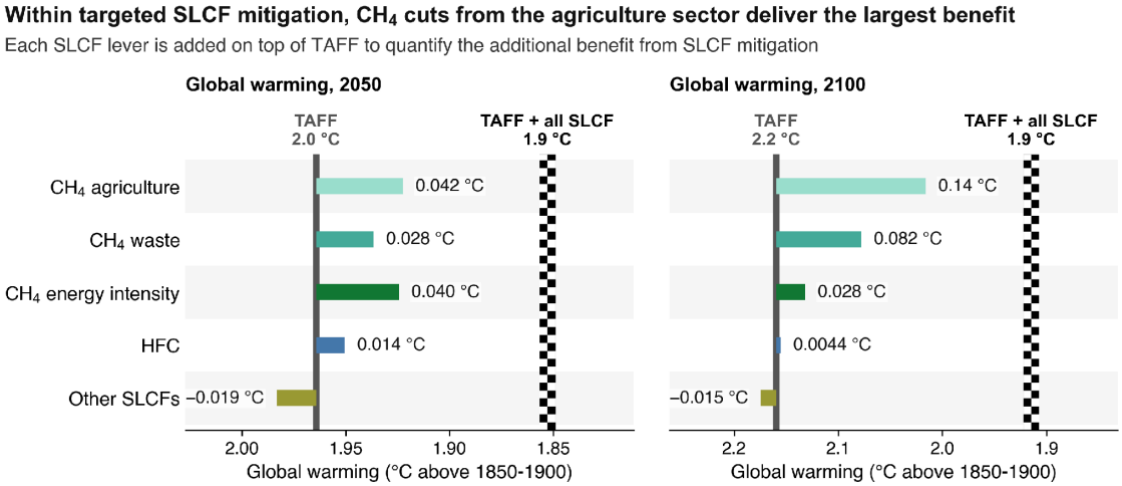


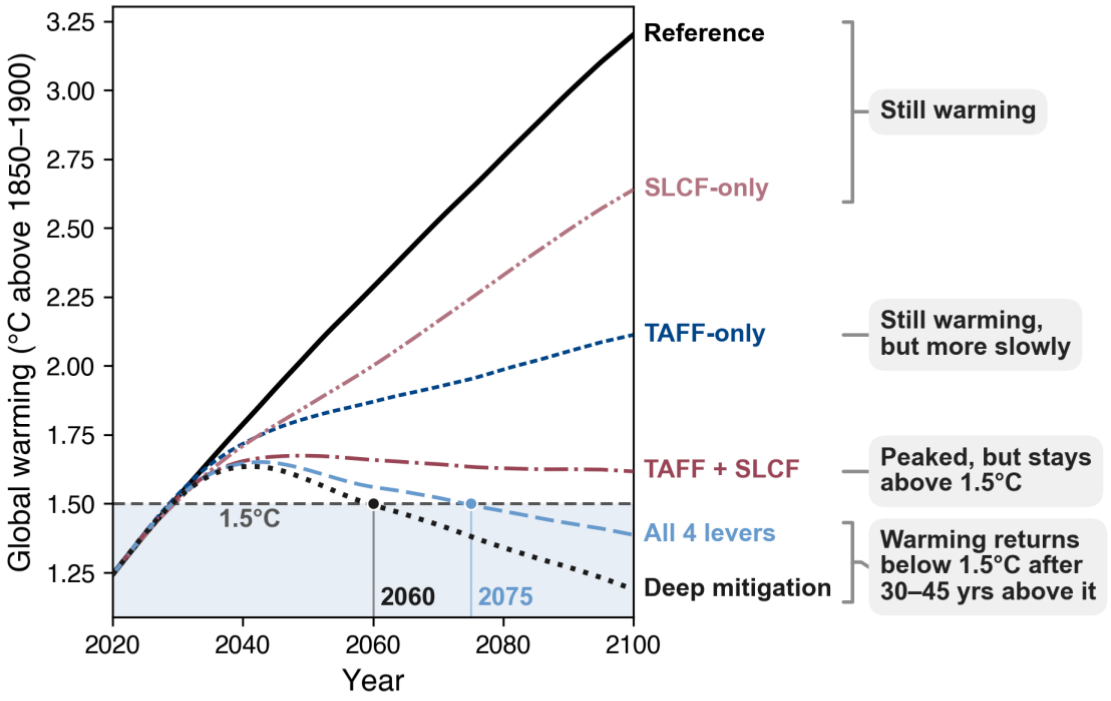
Figure 4.7 Global warming in 2050 and 2100 (relative to 1850–1900) from individual targeted SLCF measures added to TAFF under the IAS pathway. The individual SLCF measures are CH_4 reductions from energy intensity, waste and agriculture, HFC reductions, and mitigation of other SLCFs. Bars run from the TAFF scenario (grey line) towards TAFF combined with all SLCF measures (checkered finish line); labels give the avoided warming relative to the Reference pathway. Note the reversed x-axis and the different scales in each panel. All values are MAGICC v7.5.3 ensemble medians.

4.2.2. Policy-failure pathway

The policy-failure pathway, reflecting weaker, incomplete future delivery of existing policies, raises warming to 3.2°C by 2100, 0.5°C above the Reference pathway, (Figure 4.8) with a correspondingly higher near-term rate of warming across every lever (Figure 4.9). Both the SLCF-only and TAFF-only scenarios result in higher temperatures under the weaker-policy-delivery assumption. Neither lever on its own peaks before 2100 under this baseline: TAFF-only is still warming at the end of the century, at roughly 0.06°C per decade, so TAFF alone is not sufficient to halt warming under weaker policy delivery.

TAFF and targeted SLCF mitigation stabilise warming by 2100; returning to 1.5°C and below requires action across all 4 levers

Global warming under each combination of mitigation levers, 2020–2100



	Peak warming (°C)	Peak year	2100 (°C)
Reference	–	after 2100	3.2
SLCF-only	–	after 2100	2.6
TAFF-only	–	after 2100	2.1
TAFF + SLCF	1.7	2049	1.6
All 4 levers	1.7	2043	1.4
Deep mitigation	1.6	2041	1.2

Figure 4.8 GMST (relative to 1850–1900) under the Reference pathway and successively more ambitious scenarios, Policy-failure pathway, 2020–2100. The mitigation pathways are the isolated levers (SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); all four levers (TAFF, SLCF, CDR and LULUCF) combined; and the Deep Mitigation pathway, which includes additional mitigation in gases and sectors not prioritized in this study. The dashed line marks 1.5°C and markers give the year each pathway returns below it. The accompanying table reports peak warming, peak year and 2100 warming for each pathway. All values are MAGICC v7.5.3 ensemble medians.

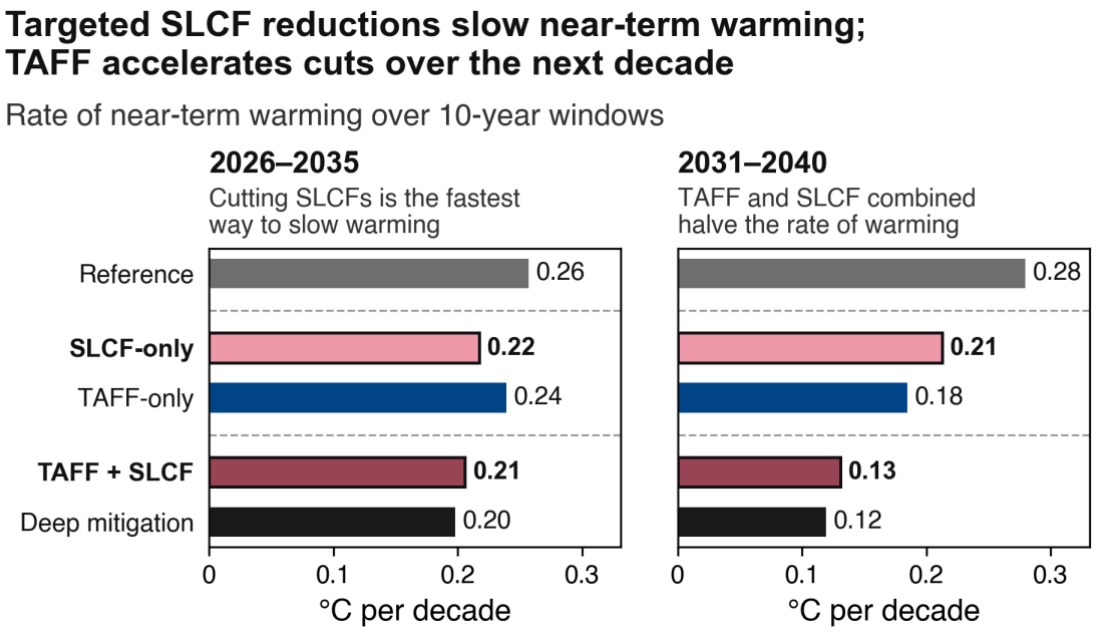


Figure 4.9 Rate of near-term warming over 2026–2035 (left panel) and 2031–2040 (right panel) by lever, Policy-failure pathway. The mitigation pathways are the isolated levers (SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); and the Deep Mitigation pathway, which includes additional mitigation in gases and sectors not prioritized in this study. The vertical grey line shows the recent historical warming rate (2021–2025). All values are MAGICC v7.5.3 ensemble medians.

In 2050, every lever avoids more warming under the Policy-failure pathway than under the Reference pathway, simply because the baseline it is measured against is worse: TAFF-only avoids 0.23°C and targeted SLCF mitigation 0.19°C, against 0.21°C and 0.12°C respectively under the Reference pathway (Figure 4.10).

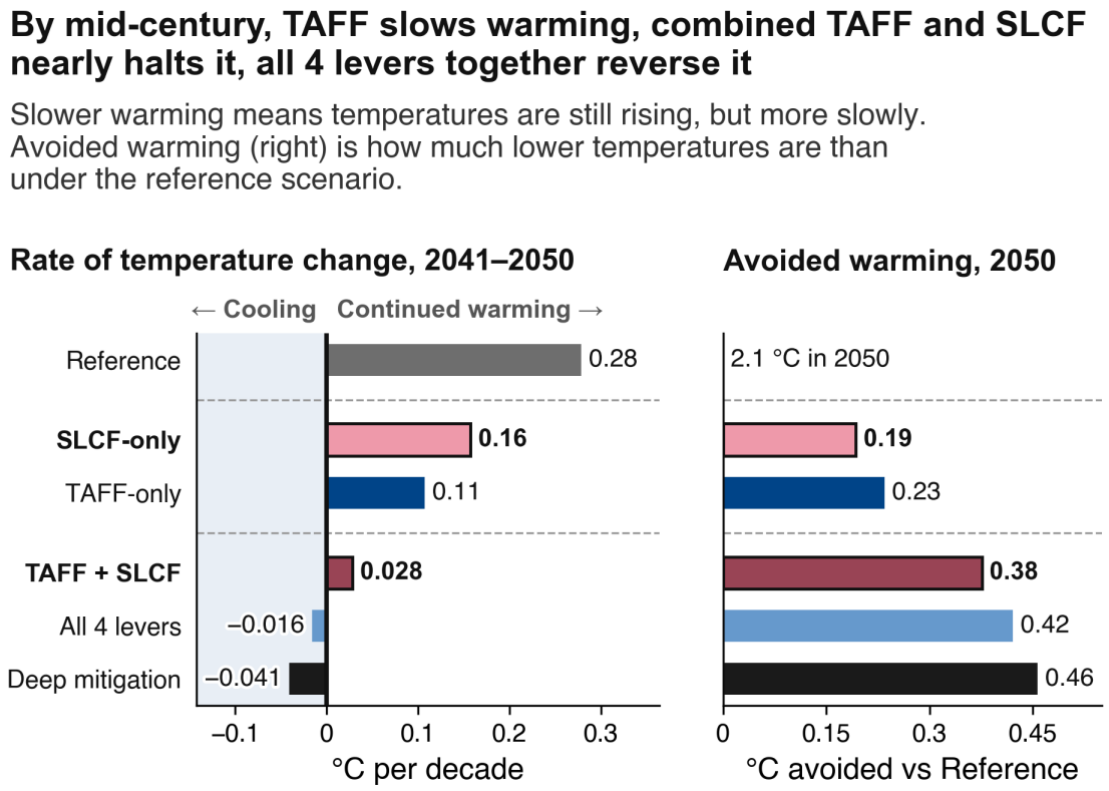


Figure 4.10 Rate of temperature change over 2041–2050 (left) and avoided warming in 2050 (right) under individual and combined mitigation levers, Policy-failure pathway. The mitigation pathways are the isolated levers (SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); all four levers (TAFF, SLCF, CDR and LULUCF) combined; and the Deep Mitigation pathway, which includes additional mitigation in gases and sectors not prioritized in this study. Labels denote avoided warming relative to the Policy-failure pathway. Negative rates indicate cooling. All values are MAGICC v7.5.3 ensemble medians.

Under the Policy-failure pathway, HFC mitigation on top of TAFF avoids 0.026°C of warming in 2050 and 0.090°C in 2100 (Figure 4.12), considerably more than under the Reference pathway, because the Policy-failure baseline does not assume Kigali Amendment compliance, whereas the Reference pathway assumes its full implementation.

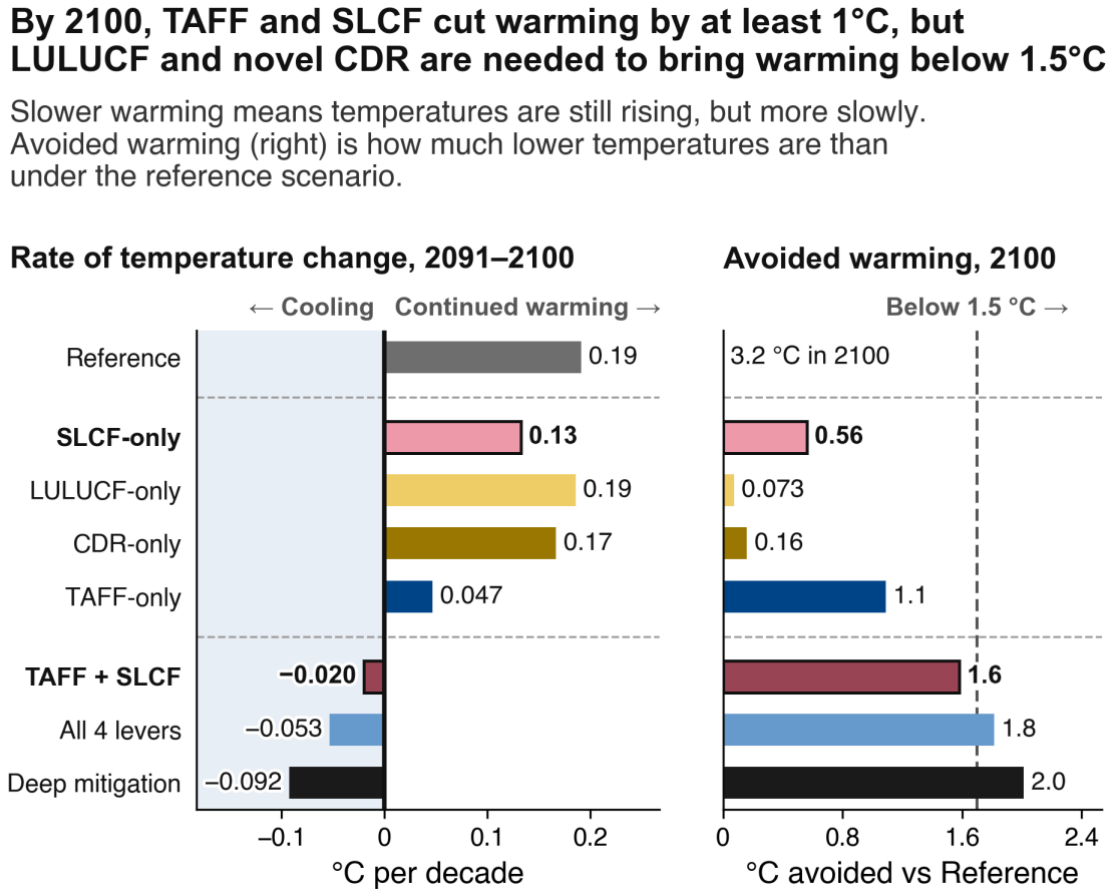


Figure 4.11 Rate of temperature change over 2091–2100 (left) and global warming in 2100 (right) under individual and combined mitigation levers, Policy-failure pathway. The mitigation pathways are the isolated levers (LULUCF-only, CDR-only, SLCF-only and TAFF-only); combined TAFF and SLCF (TAFF + SLCF); all four levers (TAFF, SLCF, CDR and LULUCF) combined; and the Deep Mitigation pathway, which includes additional mitigation in gases and sectors not prioritized in this study. Labels denote avoided warming relative to the Policy-failure pathway. Negative rates indicate cooling. All values are MAGICC v7.5.3 ensemble medians.

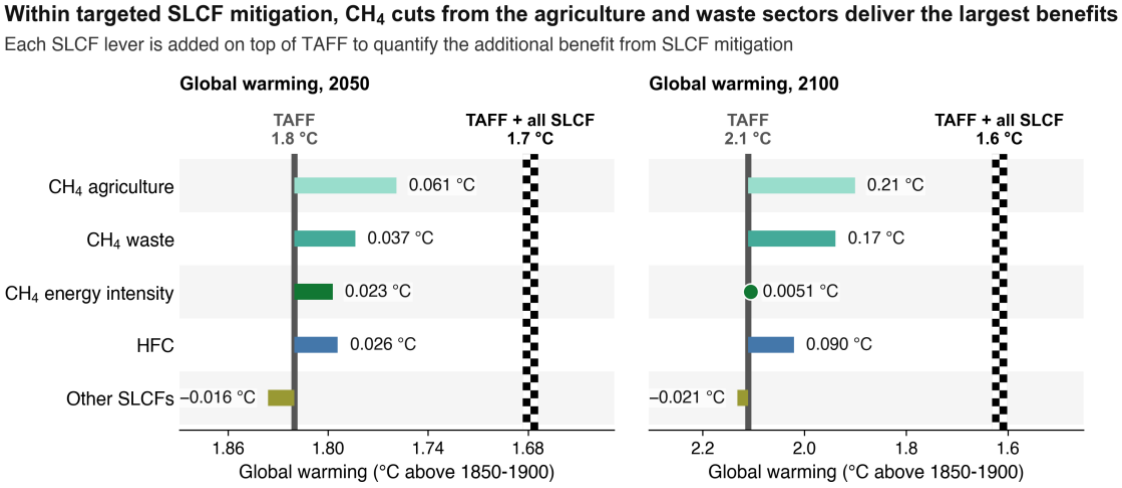


Figure 4.12 Global warming in 2050 and 2100 (relative to 1850–1900) from individual targeted SLCF measures added to TAFF, Policy-failure pathway. The individual SLCF measures are CH_4 reductions from energy intensity, waste and agriculture, HFC reductions, and mitigation of other SLCFs. Bars run from the TAFF scenario (grey line) towards TAFF combined with all SLCF measures (checkered finish line); labels give the avoided warming. Note the reversed x-axis and the different scales in each panel. All values are MAGICC v7.5.3 ensemble medians.

Together, these two sensitivity tests show the Core Scenario findings are conditional on two assumptions, but in different ways. First, TAFF's ambition, as the single most important mitigation lever in terms of avoided warming, determines the magnitude of the total achievable avoided warming from mitigation. A weaker TAFF delivery therefore reduces the total avoided warming and inflates the relative importance of targeted SLCF mitigation. When TAFF is delayed, targeted SLCF mitigation still avoids 0.12°C in 2050 and 0.29°C in 2100, exactly as it does at full TAFF ambition, but its share of the total rises because the total shrinks. Second, under the Policy-failure pathway, both TAFF and SLCF mitigation avoid more warming by 2100 because weaker policy delivery in the Reference pathway leaves more emissions unabated. Targeted SLCF mitigation, for example, avoids 0.56°C under the Policy-failure pathway, compared with 0.29°C under the Reference pathway, whereas TAFF avoids 1.1°C compared with 0.8°C. While total avoided warming changes, the ranking of the mitigation levers does not, and end-of-century temperatures for both the SLCF-only and TAFF-only pathways are higher under the Policy-failure sensitivity.

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A1. Scenario Databases

This analysis uses a combination of various datasets to construct the scenarios that are used to explore the mitigation levers and research questions. These include the historical emissions data, IAM pathways, and pathways from the Climate Action Tracker. Table A1.1 below summarises these various datasets and their provenance.

Table A1.1 Datasets used in analysis

Dataset	Source / Version / Date	Citation / URL	Used for
CEDS	v_2025_03_18	Hoesly, R., Smith, S., Ahsan, H., Prime, N., O'Rourke, P., Crippa, M., Klimont, Z., Guizzardi, D., Feng, L., Harkins, C., McDonald, B., Wang, S. (2025). CEDS v_2025_03_18 aggregate emissions [Data set]. Zenodo. https://doi.org/10.5281/zenodo.15059443	History
BB4CMIP7	DRES-CMIP-BB4CMIP7-2-0	van Marle, M.J.E., van der Werf, G.R., et al. Open biomass burning emissions for CMIP7 (DRES-CMIP-BB4CMIP7-2-0) [Data set]. input4MIPs/ESGF. https://doi.org/10.25981/ESGF.input4MIPs.CMIP7/2524040	History (fire component)
CMIP7-fastmip v1	fastmip v1, fair v2.2.4, published 2026-03-02	Smith, C. (2026). fair calibration data (fastmip v1, fair v2.2.4) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.18828694	History
PRIMAP-hist	v2.7, Sep 2025 release	Gutschow, J., Busch, D., & Pfluger, M. (2025). The PRIMAP-hist national historical emissions time series (1750-2024) v2.7 [Data set]. Zenodo. https://doi.org/10.5281/zenodo.17090760	History (fossil CO_2, rescaled to CMIP7)
Global Carbon Budget	2025 (v1.0), published 2025-11	Global Carbon Project (2025). Global Carbon Budget 2025 (Version 1.0) [Data set]. ICOS Carbon Portal. https://doi.org/10.18160/GCP-2025	History (land-use CO_2)

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EDGAR	2025 Report	Crippa, M., Guizzardi, D., Pagani, F., et al. (2025). GHG emissions of all world countries - 2025 Report. Publications Office of the EU, Luxembourg. https://doi.org/10.2905/JRC.1K6V990	History (HFC)
Velders et al. (2022)	KI-2022	Velders, G.J.M. et al. (2022). "Projections of hydrofluorocarbon (HFC) emissions and the resulting global warming based on recent trends in observed abundances and current policies." Atmos. Chem. Phys., 22, 6087-6101. https://doi.org/10.5194/acp-22-6087-2022	HFC Reference
ELEVATE	v2.0, 2025-06-13	ELEVATE Deliverable 2.3, "Development of global and national climate policy pathways," Zenodo, doi:10.5281/zenodo.15655308. https://zenodo.org/records/15655308	Reference, 1.5C
ScenarioMIP-CMIP7	2026	van Vuuren, D. P. et al. The Scenario Model Intercomparison Project for CMIP7 (ScenarioMIP-CMIP7). Geosci. Model Dev. 19, 2627–2656 (2026). https://doi.org/10.5194/gmd-19-2627-2026	Reference, 1.5C
Scenario Compass Initiative	SCI-2025 v1.0	Riahi, K. et al. (2026). Mitigation benchmarks from the 2025 community update of global emissions pathways. Preprint. https://doi.org/10.21203/rs.3.rs-8891091/v1	Reference, 1.5C
CAT-GA	COP30, 2025-11-13	Climate Action Tracker (2025). Warming Projections Global Update. Climate Analytics & NewClimate Institute. https://climateactiontracker.org/documents/1348/CAT_2025-11-13_GlobalUpdate_COP30.pdf	Reference, Policy-failure

REMIND-HPA	REMIND 3.5, NPE-core	Climate Analytics & PIK (2025). "Rescuing 1.5°C: new evidence on the highest possible ambition to deliver the Paris Agreement." https://climateanalytics.org/publications/rescuing-1-5c	Deep Mitigation, IAS
GAINS	v4.1b, 2026-04-27	Höglund-Isaksson, L. et al. (2020). "Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe." Environ. Res. Commun. 2, 025004. https://doi.org/10.1088/2515-7620/ab7457	Policy-failure CH_4

A2. Gas Reference

In this study we consider 12 gases. Table A2.1 lists them with their atmospheric lifetimes and shows which are short-lived climate forcers and which act as cooling aerosols. CO_2 is included because it is the lead gas in the scenario construction, though it is neither.

Table A2.1 Gas reference table

#	Gas	Name	Lifetime	SLCF	Cooling Aerosol
1	CO_2	Carbon Dioxide	Centuries+	No	No
2	CH_4	Methane	7-12 yr	Yes	No
3	BC	Black Carbon	4-12 days	Yes	No
4	OC	Organic Carbon	Days	No	Yes
5	NO_x	Nitrogen Oxides	2-24 hr	No	Yes (NO3)
6	VOC	Volatile Organic Compounds	Minutes-months	Yes (indirect via O3)	No
7	SO_2	Sulphur Dioxide	4-10 days	No	Yes
8	HFCs	Hydrofluorocarbons	~15 yr avg	Yes	No
9	CO	Carbon Monoxide	1-2 months	Yes (indirect via CH_4 lifetime extension)	No
10	N_2O*	Nitrous Oxide	~109 yr	No	No
11	PFC*	Perfluorocarbons	10,000+ yr	No	No
12	SF_6*	Sulphur Hexafluoride	~3,200 yr	No	No

** = deprioritized in SLCF (fixed at reference, not driven by any mitigation lever).*

A3. Scenario List

Every scenario belongs to one of three buckets. Bucket A enables comparison of the four mitigation levers against each other, isolated and combined, answering RQ2. Bucket B enables ranking of the SLCF sub-levers against each other, answering RQ3, and also supports RQ1 (the standalone temperature benefit of targeted SLCF mitigation) through its CPP-isolated reading. Bucket C enables quantification of aerosol unmasking as cooling pollutants decline, answering RQ4.

- Bucket A (comparing levers): the current-policy baseline, the full-ambition pathway, each lever alone at highest ambition, CDR alone, all three levers combined, and a TAFF+SLCF-only pairwise comparison.
- Bucket B (ranking SLCF sub-levers): the five SLCF sub-levers (CH_4 energy-intensity, CH_4 agriculture, CH_4 waste, HFCs, other-sector co-benefits), reported two ways as equal peers: isolated from current policy (a clean ranking, no order-dependency) and layered on top of the fossil-fuel lever (capturing the real interaction between fossil decarbonization and each pollutant's own remaining headroom). The two readings can disagree: CH_4 energy-intensity is the single largest lever in isolation but nearly disappears once fossil decarbonization has already happened, because that alone already captures most of the same reduction.
- Bucket C (aerosol unmasking): a cumulative build (current policy, then fossil decarbonization, then all SLCF action added on top) paired with an isolated decomposition of the energy sector's own warming and cooling co-pollutants, to show how much extra warming is unmasked as cooling aerosols decline.

Table A3.1 summarises this experimental setup in full. Scenario names follow the pipeline's own convention: CPP denotes the Reference pathway, HPA the highest possible ambition used in Deep Mitigation, and the remaining elements name the levers switched to HPA. These are the identifiers used in the accompanying data files; the "What it is" column gives the plain-language description.

Table A3.1 Scenario list

ID	Scenario ID	What it is
A	Comparing levers, incl. CDR + TAFF/SLCF pairwise (A8)	
A1	CPP_ALL	Current policy baseline, every lever at CPP
A2	HPA_ALL_PLUS_DEPRIORITIZED	Full ambition, every lever incl. deprioritized gases, at HPA (CDR: combined BECCS+DACCS)

A3	TAFF_HPA	Fossil/Energy lever alone at HPA (CO_2: no CDR credit)
A4	SLCF_HPA	SLCF lever alone at HPA
A5	LAND_HPA	LULUCF lever alone at HPA
A6	CPP_all_CDRreduced	CDR (engineered, BECCS+DACCS) alone to HPA, isolated from CPP_ALL
A7	TAFF_SLCF_LAND_HPA	TAFF, targeted SLCF and LULUCF combined, the combined-total reference (CDR: combined BECCS+DACCS)
A8	TAFF_Base_HPA_AllSLCF	TAFF+SLCF together, no land (same run as B12/C3) (CO_2: no CDR term)
B	SLCF sub-levers, B1-B5 isolated from CPP, B6-B12 layered on TAFF	
B1	CPP_all_CH4Intensityreduced	CH_4 energy-intensity policy alone to HPA, isolated from CPP_ALL
2 -B2	CPP_all_CH4Agreduced	CH_4 agriculture alone to HPA, isolated from CPP_ALL
B3	CPP_all_CH4Wastereduced	CH_4 waste alone to HPA, isolated from CPP_ALL
B4	CPP_all_HFCreduced	HFCs alone to HPA, isolated from CPP_ALL
B5	CPP_all_SLCFOtherreduced	Other-sector SLCF co-benefits alone to HPA, isolated from CPP_ALL
B6-B12 below: same 5 sub-levers, layered on TAFF_HPA instead (base = A3)		
B6	TAFF_HPA	Baseline for this layered series (same run as A3/C2) (CO_2: no CDR credit)
B7	TAFF_Base_HPA_CH4EnergyIntensity	+ CH_4 energy-intensity policy, on top of TAFF_HPA
B8	TAFF_Base_HPA_CH4Agriculture	+ CH_4 agriculture, on top of TAFF_HPA
B9	TAFF_Base_HPA_CH4Waste	+ CH_4 waste, on top of TAFF_HPA
B10	TAFF_Base_HPA_HFC	+ HFCs, on top of TAFF_HPA
B11	TAFF_Base_HPA_OtherSLCF	+ other-sector SLCF co-benefits, on top of TAFF_HPA
B12	TAFF_Base_HPA_AllSLCF	+ all SLCF sub-levers together (same run as A8/C3) (CO_2: no CDR term)
C	Aerosol unmasking, C1-C3 cumulative, C4-C8 isolated	
C1	CPP_ALL	Current policy baseline (same run as A1), cumulative anchor
C2	TAFF_HPA	+ fossil/Energy lever (same run as A3/B6), cumulative (CO_2: no CDR credit)

C3	TAFF_Base_HPA_AllSLCF	+ all SLCF on top of that (same run as A8/B12), cumulative (CO_2: no CDR term)
C4-C8 below: each isolated from CPP_ALL		
C4	CPP_all_CO2reduced	CO_2|Energy alone to HPA, isolated from CPP_ALL
C5	CPP_all_CH4reduced	CH_4|Energy alone to HPA, isolated from CPP_ALL
C6	CPP_all_WarmingCoreduced	Energy-sector warming co-pollutants (BC, CO) alone to HPA, isolated from CPP_ALL
C7	CPP_all_CoolingCoreduced	Energy-sector cooling co-pollutants (OC, Sulphur) alone to HPA, isolated from CPP_ALL
C8	CPP_all_MixedCoreduced	Energy-sector mixed/unreactive co-pollutants (NO_x, VOC, genuinely competing warming/cooling mechanisms per AR6) alone to HPA, isolated from CPP_ALL


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