CARBON BUDGETS

FROM ESTIMATION TO APPLICATION

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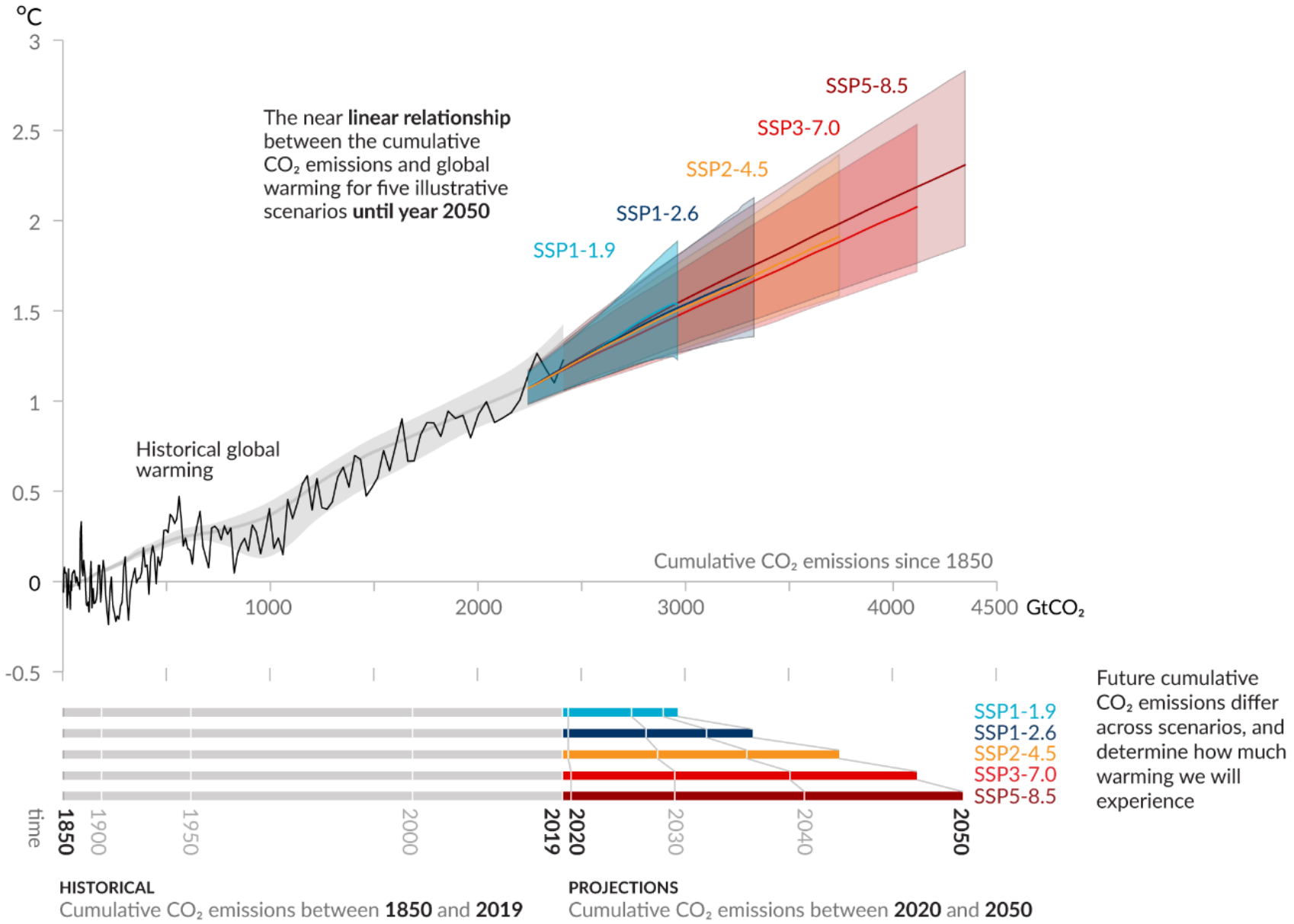
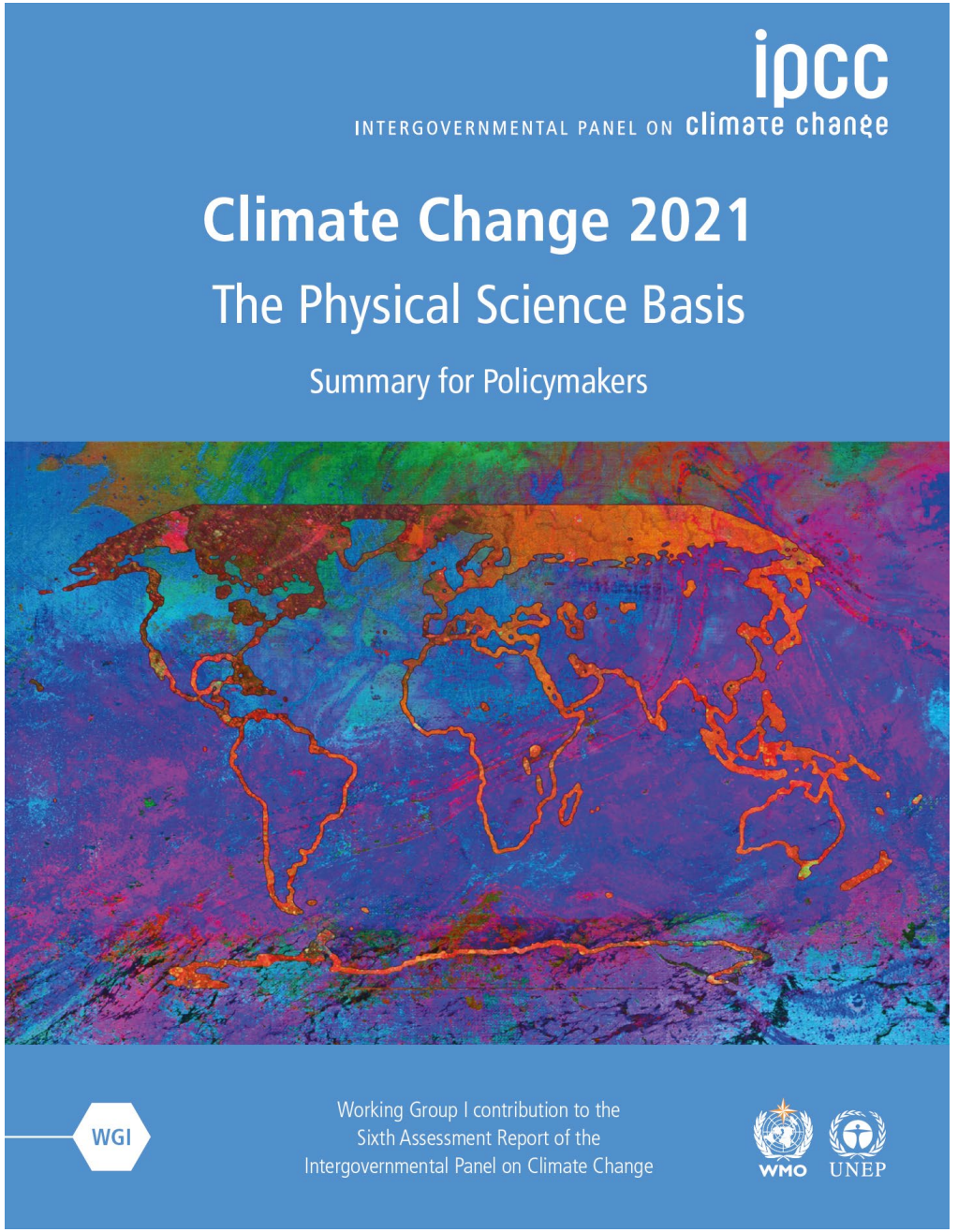
Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



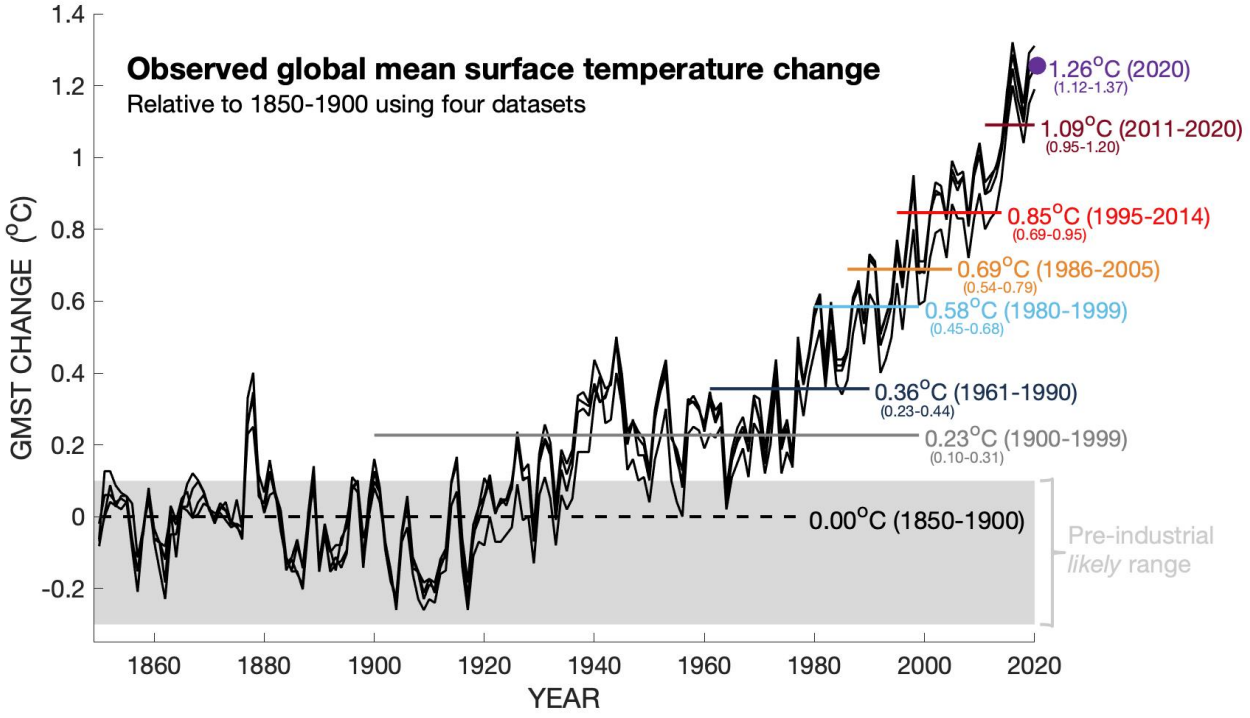
IPCC AR6 WG1 Figure SPM.10

D.1.1 This Report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to *likely* cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C.[41] This is a narrower range compared to AR5 and SR1.5. This quantity is referred to as the transient climate response to cumulative CO_2 emissions (TCRE). This relationship implies that reaching net zero anthropogenic CO_2 emissions[42] is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a carbon budget.[43] {5.4, 5.5, TS.1.3, TS.3.3, Box TS.5} (Figure SPM.10)



Complicating factors in estimating the budget

- Magnitude of warming per tonne CO_2
- Assumed warming to date
- Assumed future non-CO_2 emissions
- Magnitude of future non-CO_2 warming

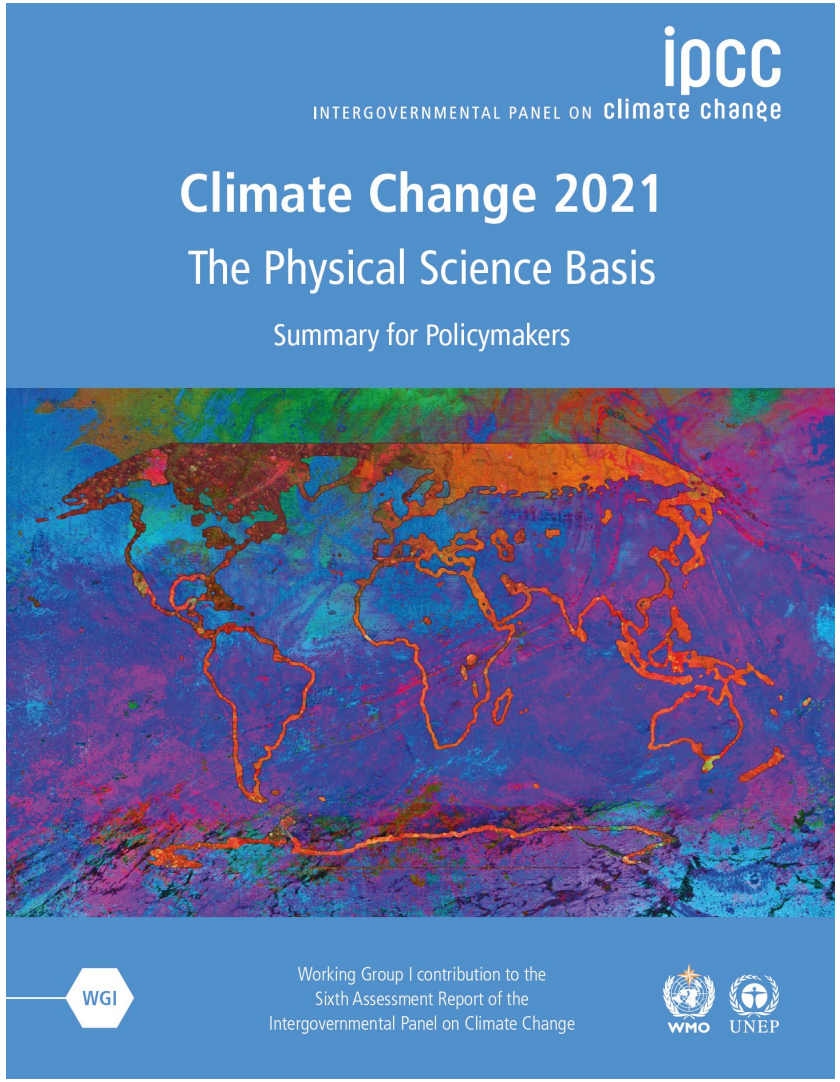


IPCC AR6 2021, Figure 1.12
Getty Images; Brendan Gogarty; Singkham; iStockphoto.com/zeljkosantrac

The Remaining Carbon Budget Framework of the IPCC

A transparent framework for estimating the **remaining carbon budget**

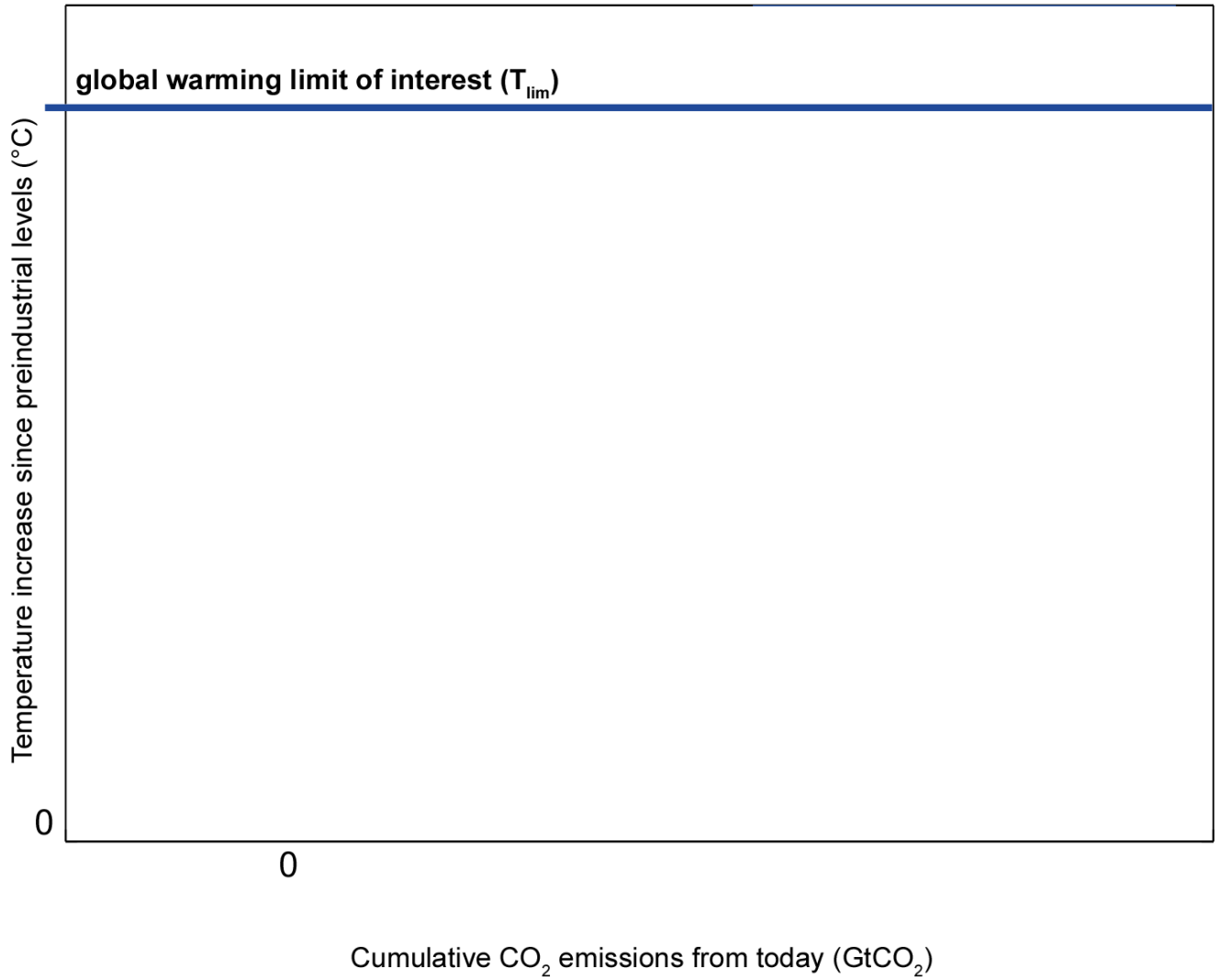
"the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers."



The Remaining Carbon Budget Framework of the IPCC

Five components:

IPCC AR6 assessment:



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

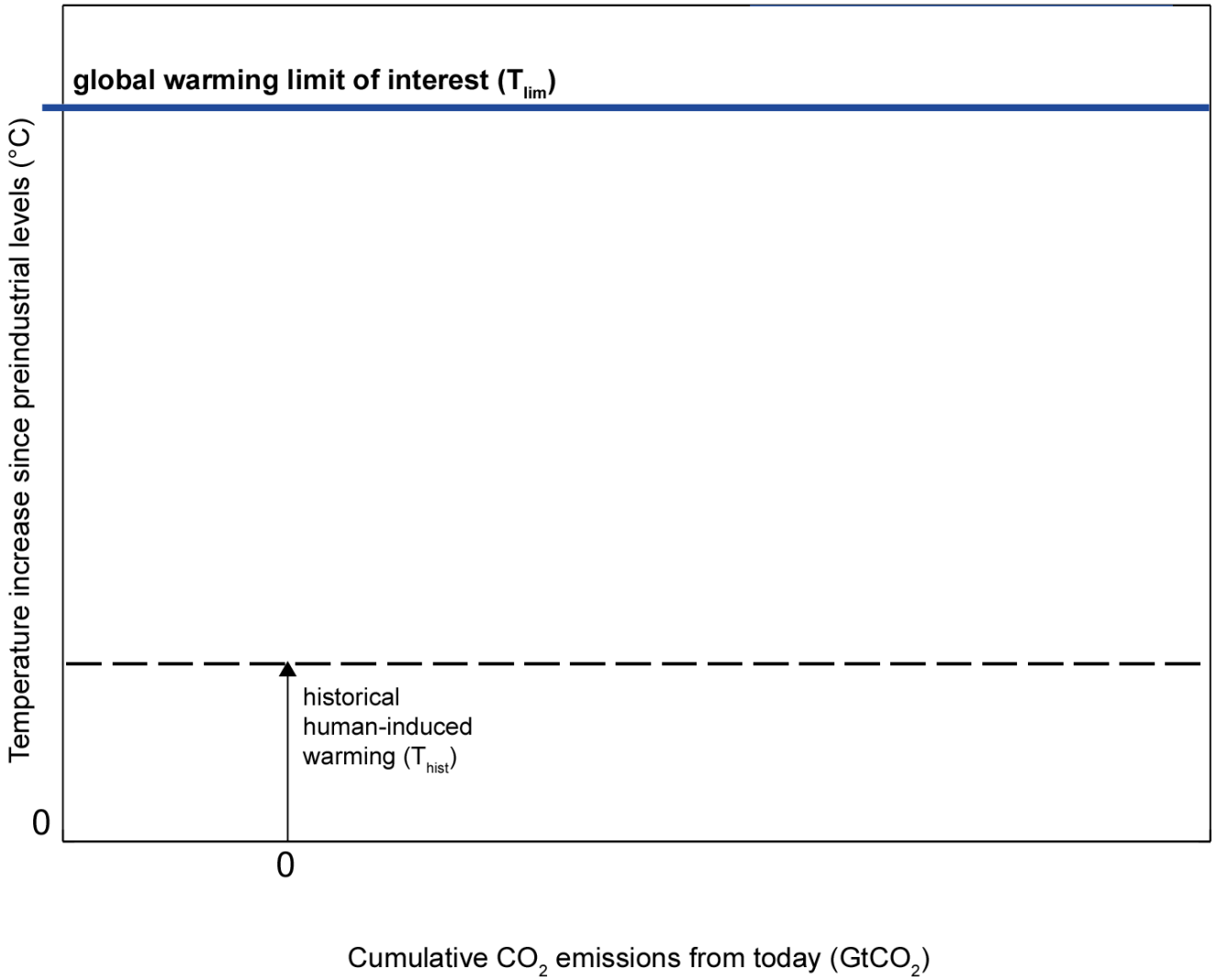
The Remaining Carbon Budget Framework of the IPCC

Five components:

- Historical warming to date

IPCC AR6 assessment:

- Human-induced warming from 1850-1900 until 2010-2019
- 1.07°C (0.8-1.3°C *likely* range)



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

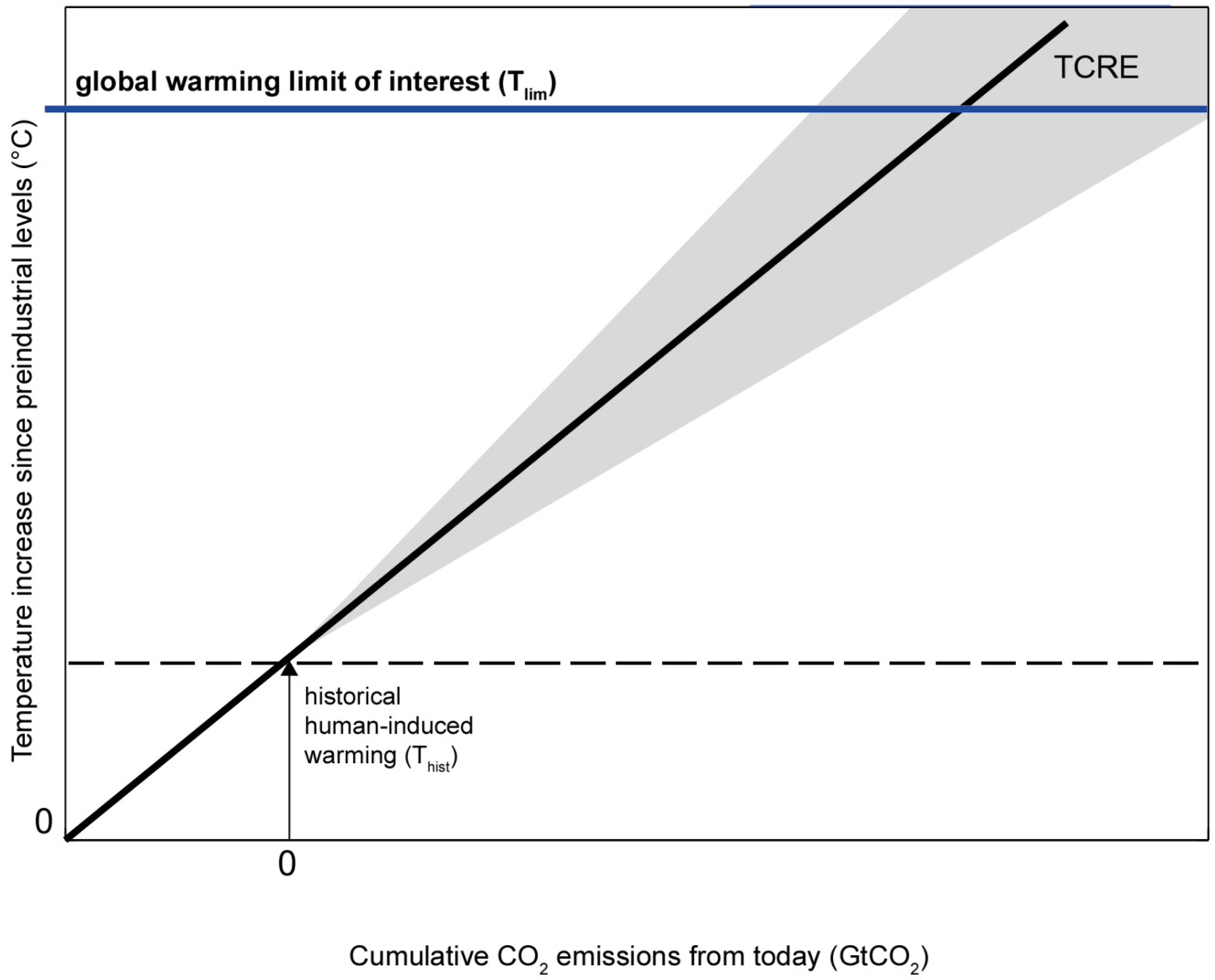
The Remaining Carbon Budget Framework of the IPCC

Five components:

- Historical warming to date
- Transient climate response to cumulative emissions of carbon dioxide (TCRE)

IPCC AR6 assessment:

- 1.0-2.3°C / 1000 PgC
- Best estimate of 1.65°C / 1000 PgC
- Normally distributed uncertainty



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

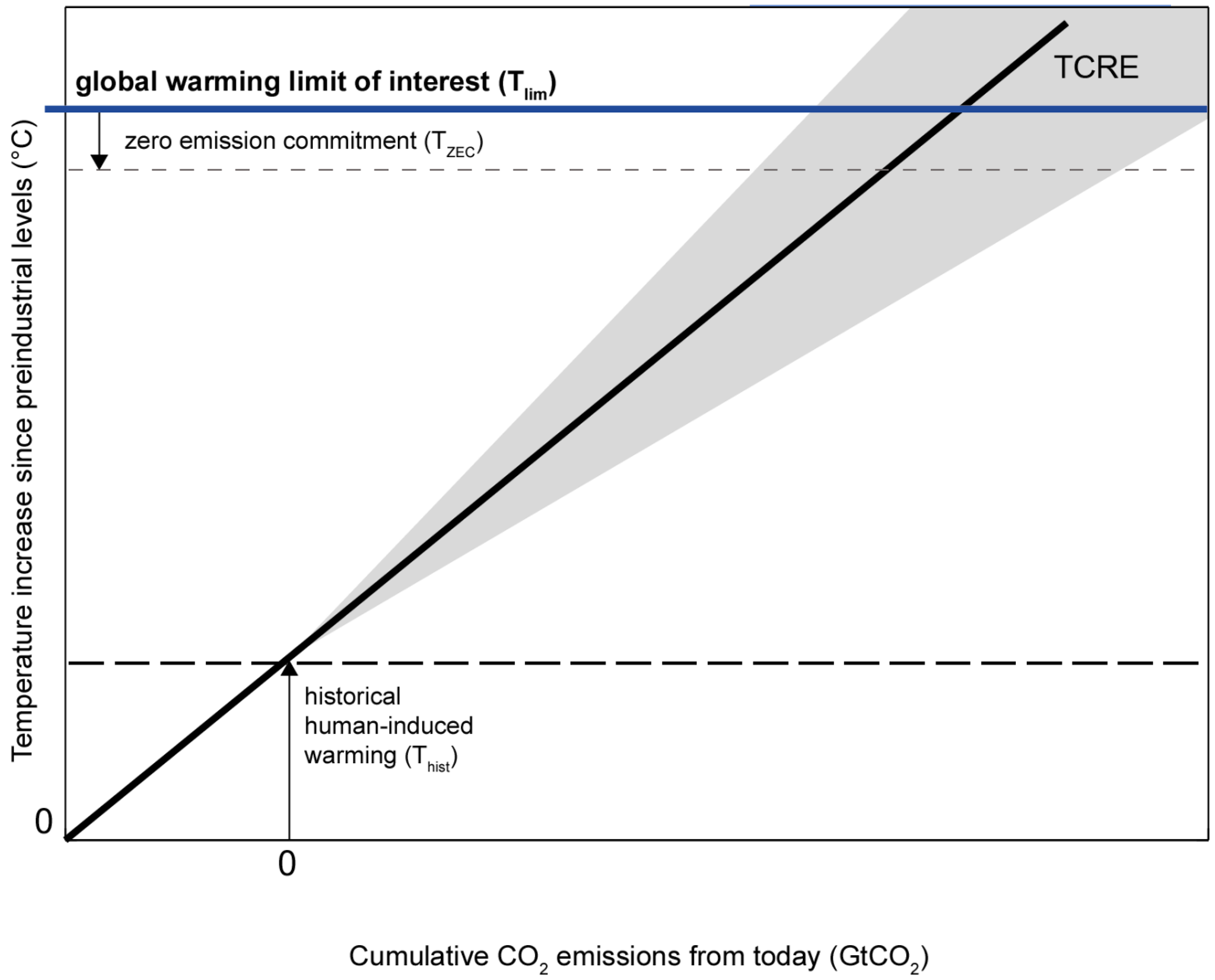
The Remaining Carbon Budget Framework of the IPCC

Five components:

- Historical warming to date
- Transient climate response to cumulative emissions of carbon dioxide (TCRE)
- Zero emission commitment (ZEC)

IPCC AR6 assessment:

- Best estimate: zero
- *Likely* range: about ±15% of total warming



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

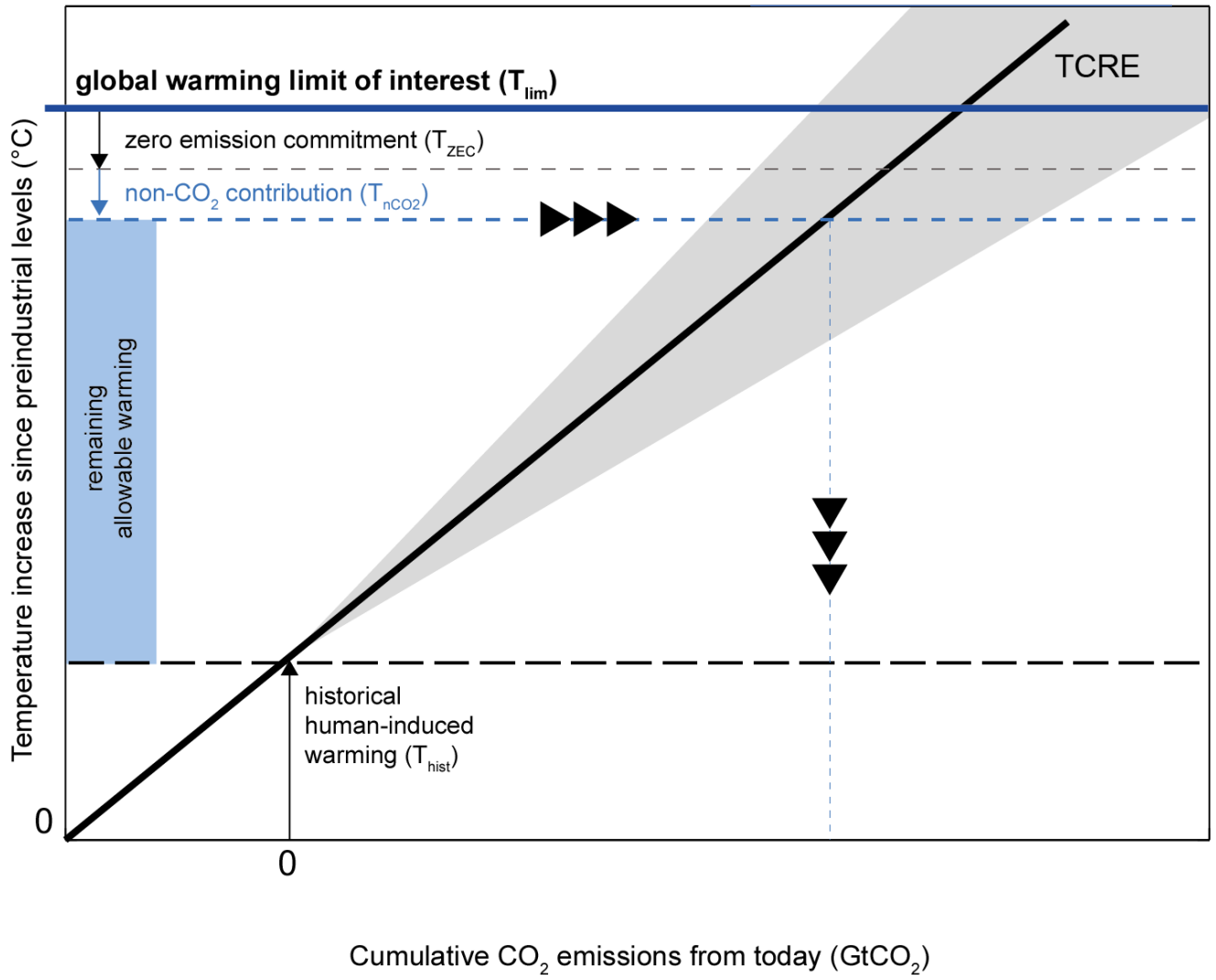
The Remaining Carbon Budget Framework of the IPCC

Five components:

- Historical warming to date
- Transient climate response to cumulative emissions of carbon dioxide (TCRE)
- Zero emission commitment (ZEC)
- Projected future non-CO_2 temperature contribution

IPCC AR6 assessment:

- Based on scenario literature
- Future non-CO_2 warming at time global CO_2 emission become net zero
- Estimated with simple climate models MAGICC & FaIR



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

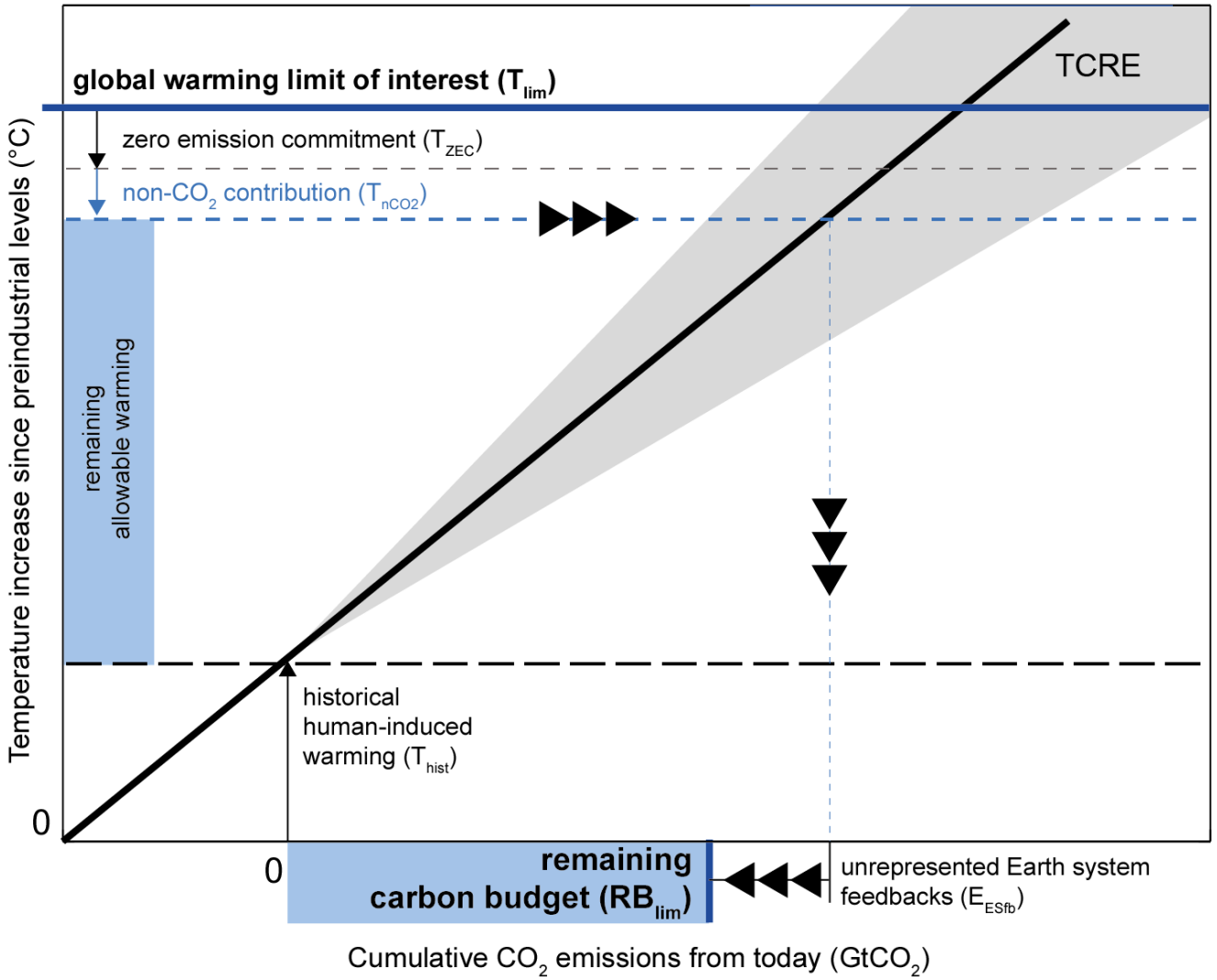
The Remaining Carbon Budget Framework of the IPCC

Five components:

- Historical warming to date
- Transient climate response to cumulative emissions of carbon dioxide (TCRE)
- Zero emission commitment (ZEC)
- Projected future non-CO_2 temperature contribution
- Unrepresented Earth system feedbacks

IPCC AR6 assessment:

- Integrated in adjustment to TCRE
- 7 ±27 PgC K^{-1} (1-sigma range)
- Includes, estimates of:
  - Permafrost thawing
  - Nitrogen cycle feedback
  - Atmospheric chemistry feedbacks, …



IPCC SR1.5; Rogelj et al, 2019; IPCC AR6 2021

FROM ESTIMATION TO APPLICATION

United Nations Framework Convention on Climate Change

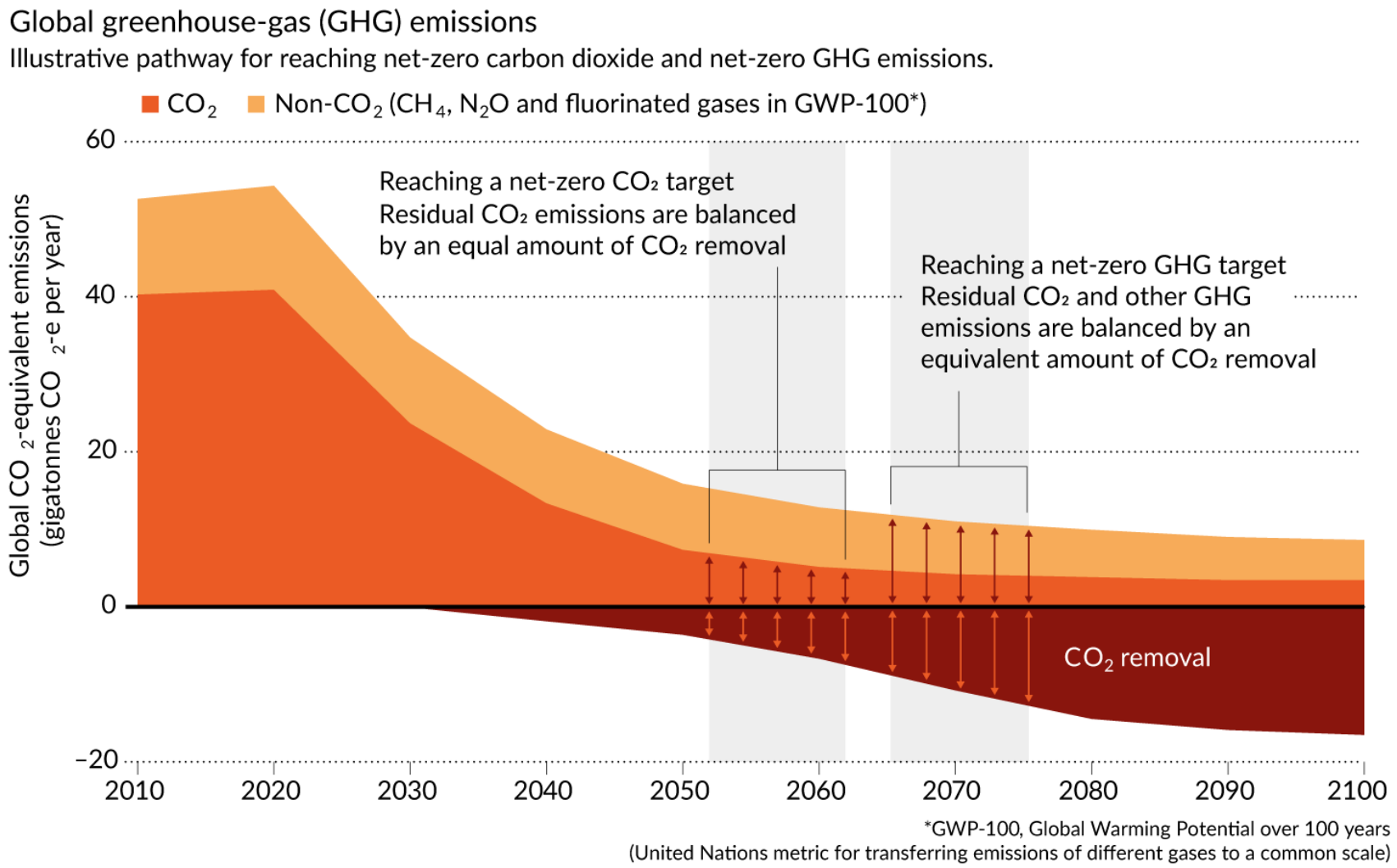
PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Size of remaining carbon budget and impact of success of reducing non-CO_2 emissions

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

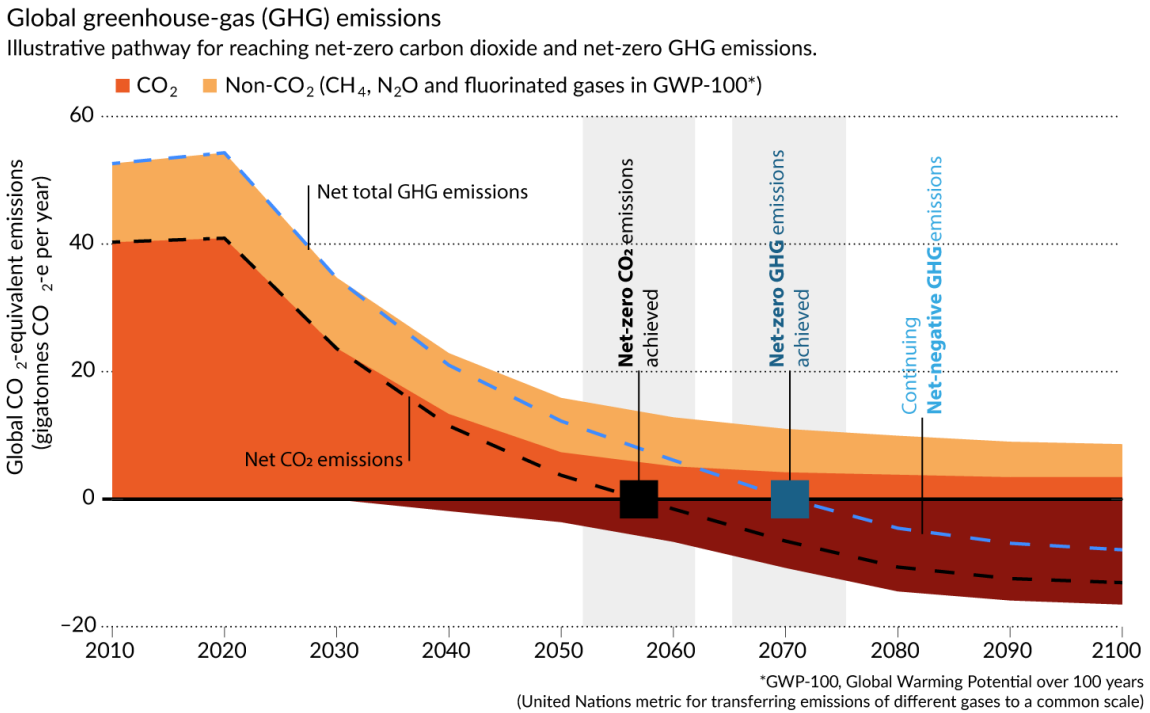
IPCC AR6 WG1 Table SPM.2

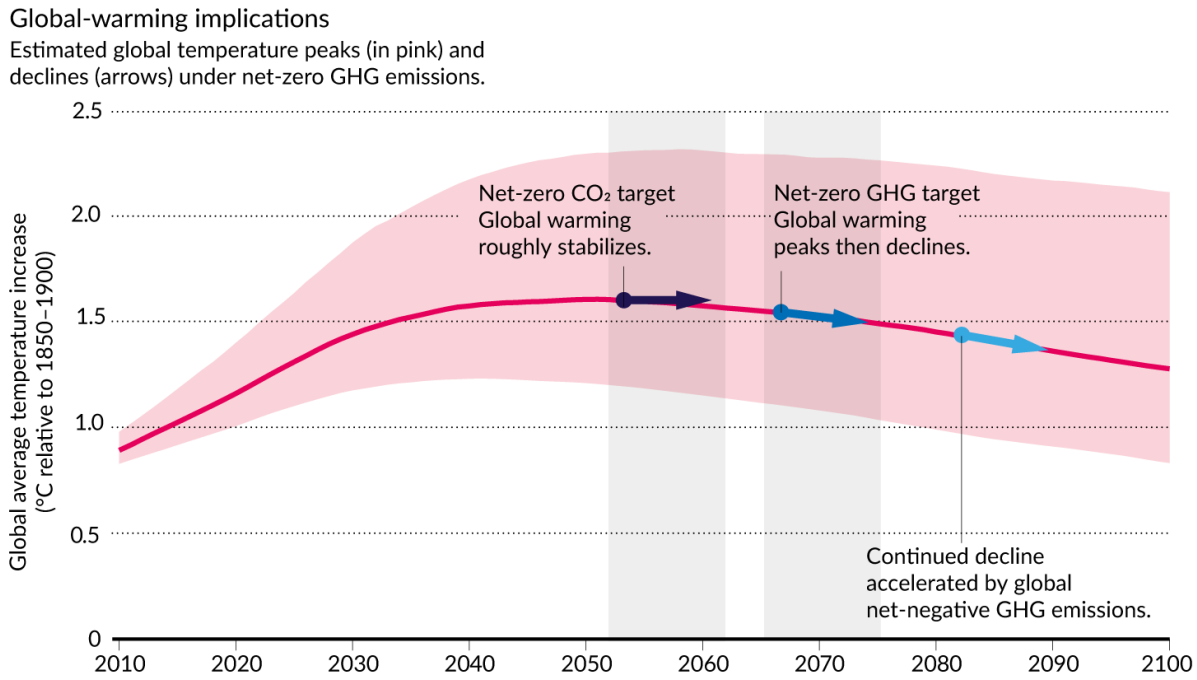
Carbon budget implications: net zero targets



Rogelj et al, Nature (2021) DOI: 10.1038/d41586-021-00662-3

The Paris Agreement net-zero target achieves more than stabilization: A peak and decline in global warming





Rogelj et al, Nature (2021) DOI: 10.1038/d41586-021-00662-3

Announced net-zero targets are vague and ambiguous: a need for improvement

A gold standard for net-zero targets:

10 guidelines for rigorous and clearer targets

Three areas:

1. Scope
2. Adequacy & fairness
3. Long-term roadmap

Rogelj et al, Nature (2021) DOI: 10.1038/d41586-021-00662-3

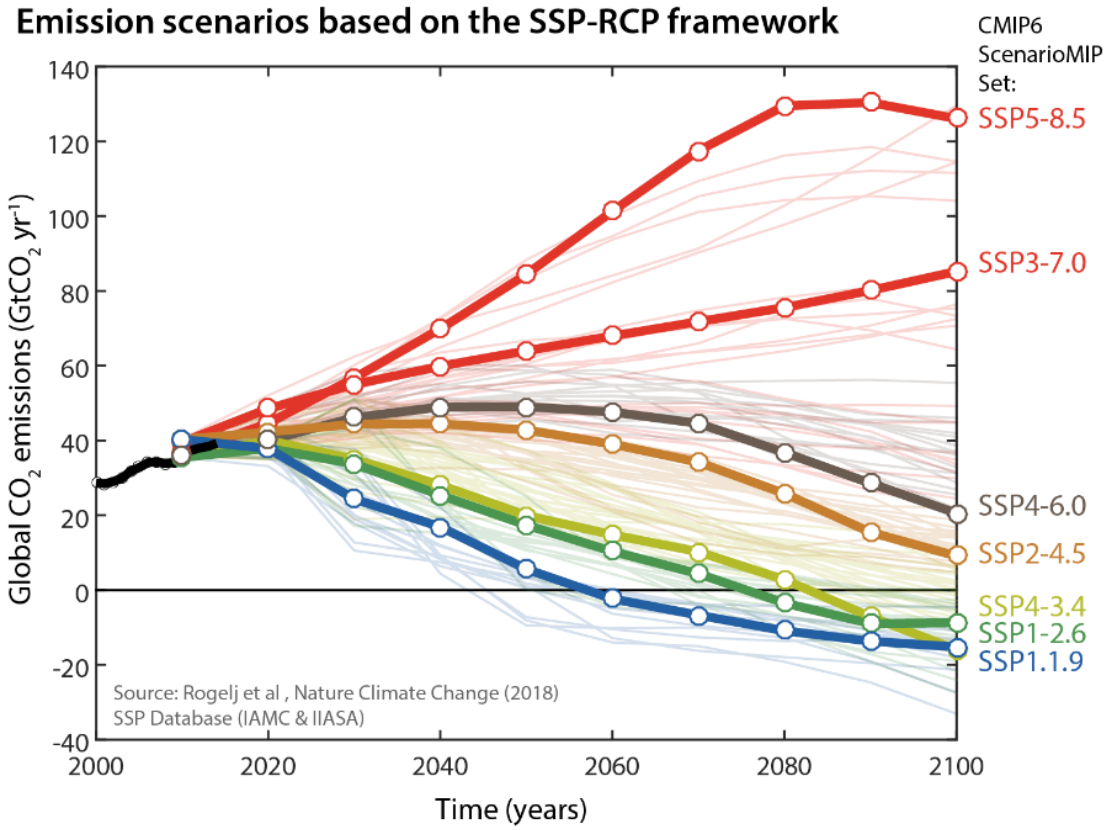
Implications: a new scenario framework to avoid ‘unfair and risky’ scenarios

- **Current situation:**

Focus on **end-of-century (2100)** outcome

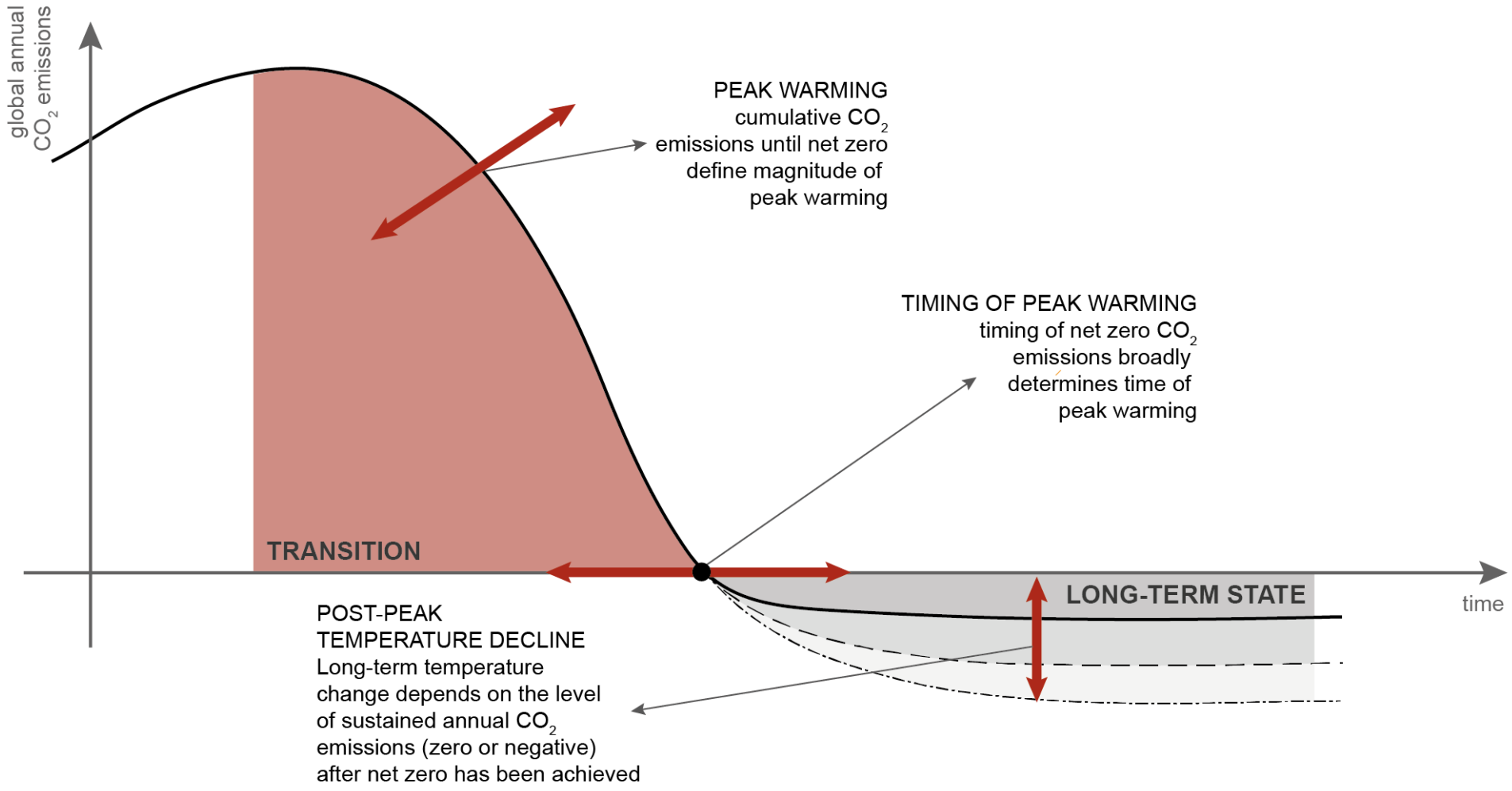
- **Consequences:**

1. Climate policy inconsistency & cognitive dissonance (overshooting)
2. Intergenerational equity & net carbon-dioxide removal (CDR)
3. Not directly applicable to Paris Agreement
4. Imprecise economic recommendations



Rogelj et al, Nature (2019b) DOI: 10.1038/s41586-019-1541-4

Implications: a new scenario framework to avoid ‘unfair and risky’ scenarios



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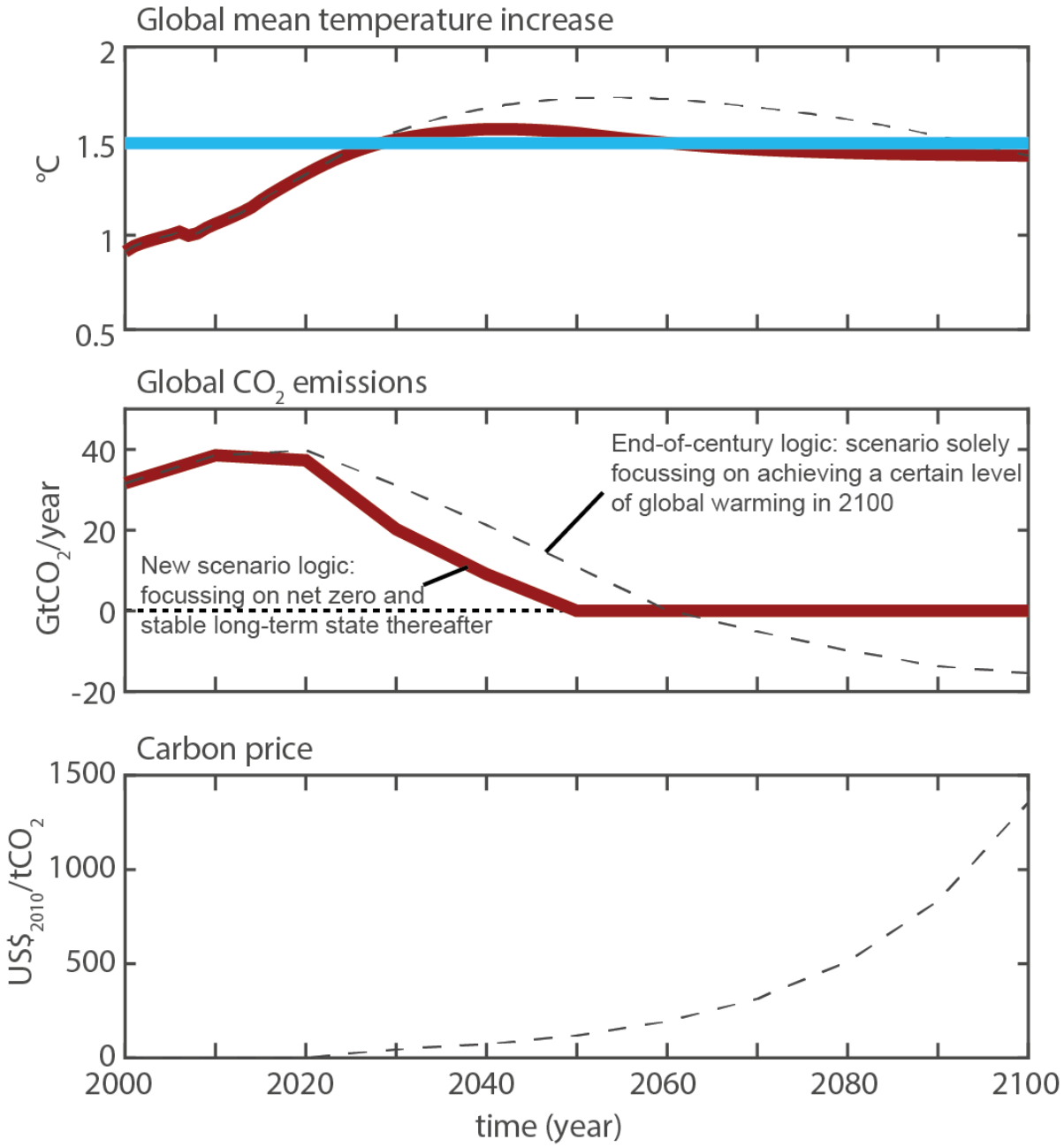
Implications of new scenario logic

- Timing of cost-effective climate action for Paris Agreement becomes discount-rate independent



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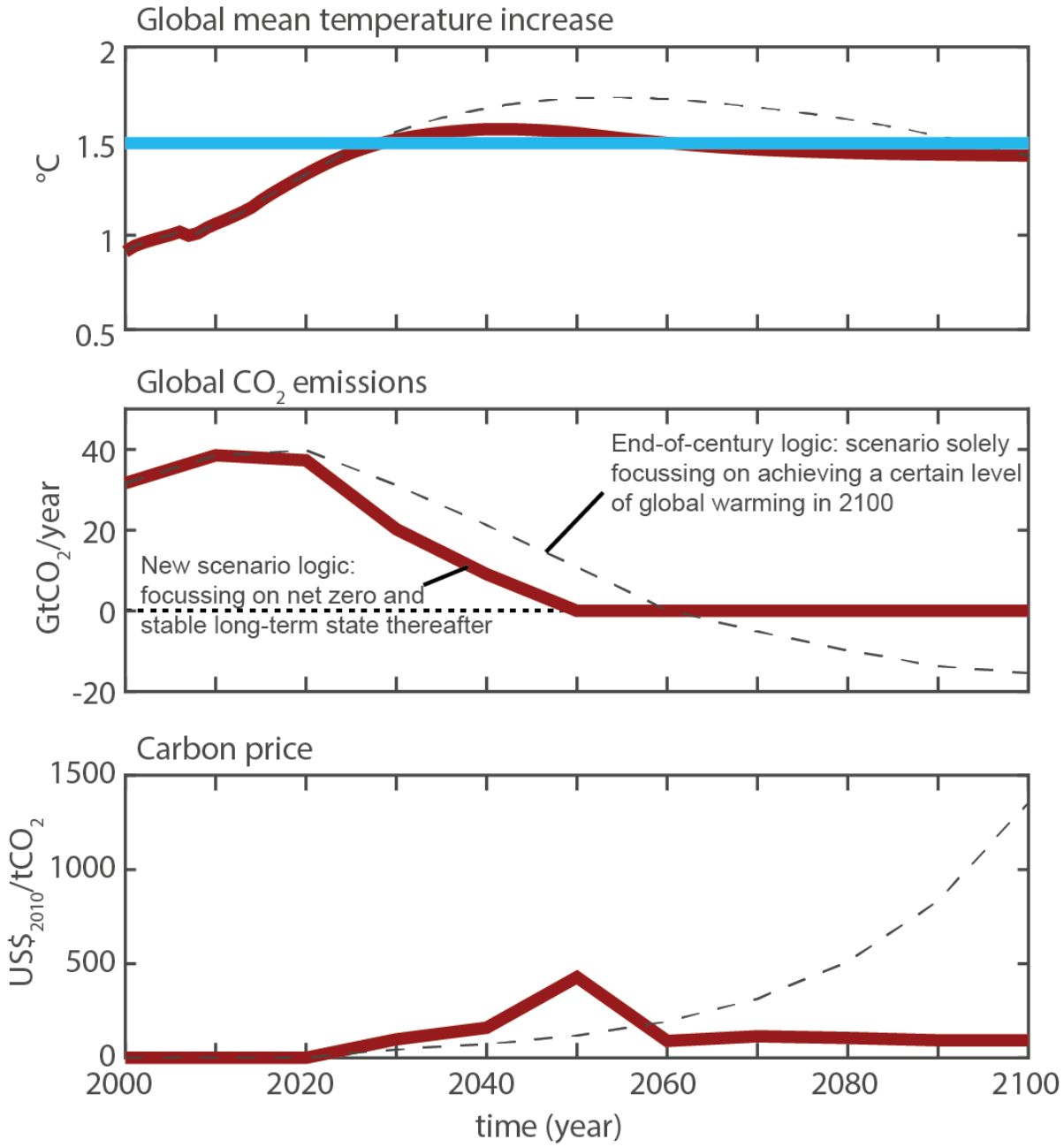
Implications of new scenario logic

- Timing of cost-effective climate action for Paris Agreement becomes discount-rate independent
- Fundamental shift in perception of effort of climate change mitigation over time



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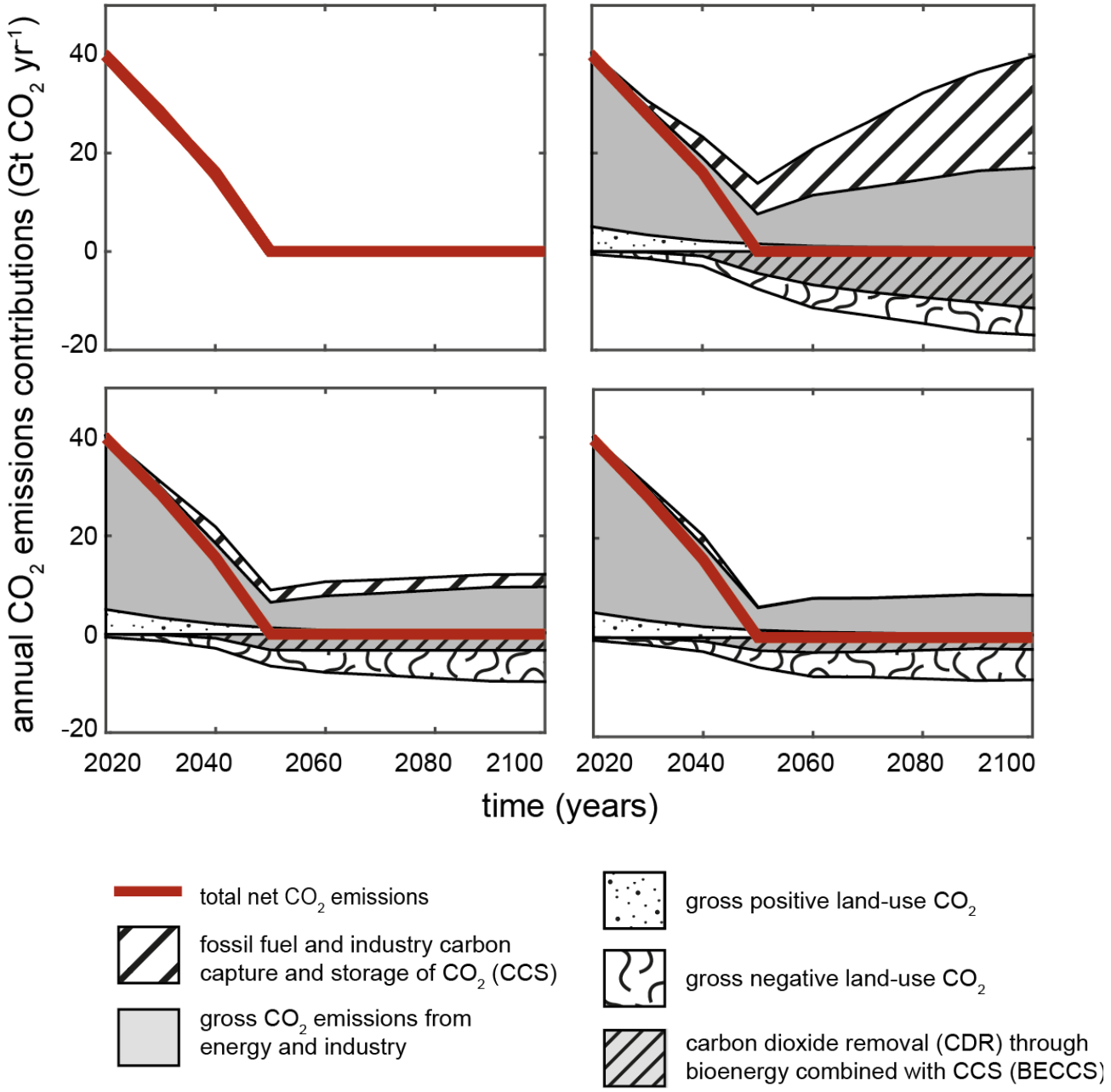
Implications of new scenario logic

- Timing of cost-effective climate action for Paris Agreement becomes discount-rate independent
- Fundamental shift in perception of effort of climate change mitigation over time
- Exploration of sustainable development implications without shifting climate ambition goal posts



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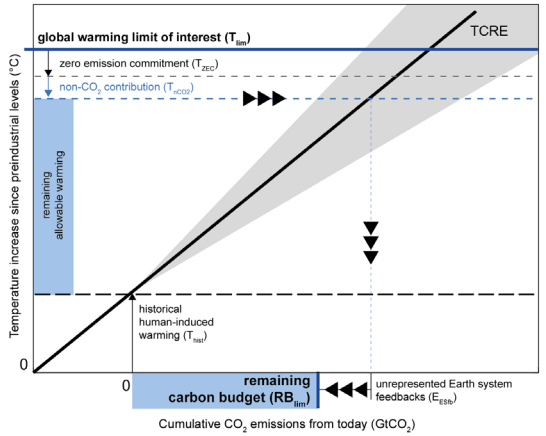
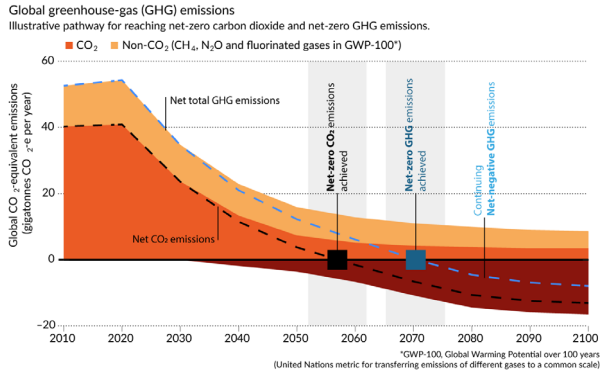
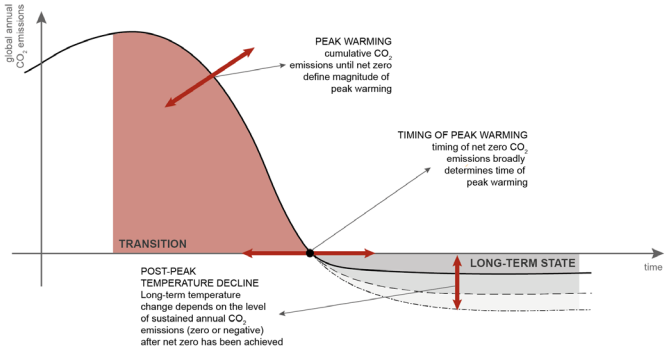
- Rogelj, J., Forster, P.M., Kriegler, E., Smith, C.J., Séférian, R., 2019. Estimating and tracking the remaining carbon budget for stringent climate targets. Nature 571, 335–342. https://doi.org/10.1038/s41586-019-1368-z
- Rogelj, J., Geden, O., Cowie, A., Reisinger, A., 2021. Three ways to improve net-zero emissions targets. Nature 591, 365–368. https://doi.org/10.1038/d41586-021-00662-3
- Rogelj, J., Huppmann, D., Krey, V., Riahi, K., Clarke, L., Gidden, M., Nicholls, Z., Meinshausen, M., 2019. A new scenario logic for the Paris Agreement long-term temperature goal. Nature 573, 357–363. https://doi.org/10.1038/s41586-019-1541-4







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