OVERSHOOT:
Challenges and choices after we exceed 1.5°C

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Lecture series CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici

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ACKNOWLEDGEMENTS

ANNUAL REVIEWS

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Annual Review of Environment and Resources

Overshoot: A Conceptual Review of Exceeding and Returning to Global Warming of 1.5°C

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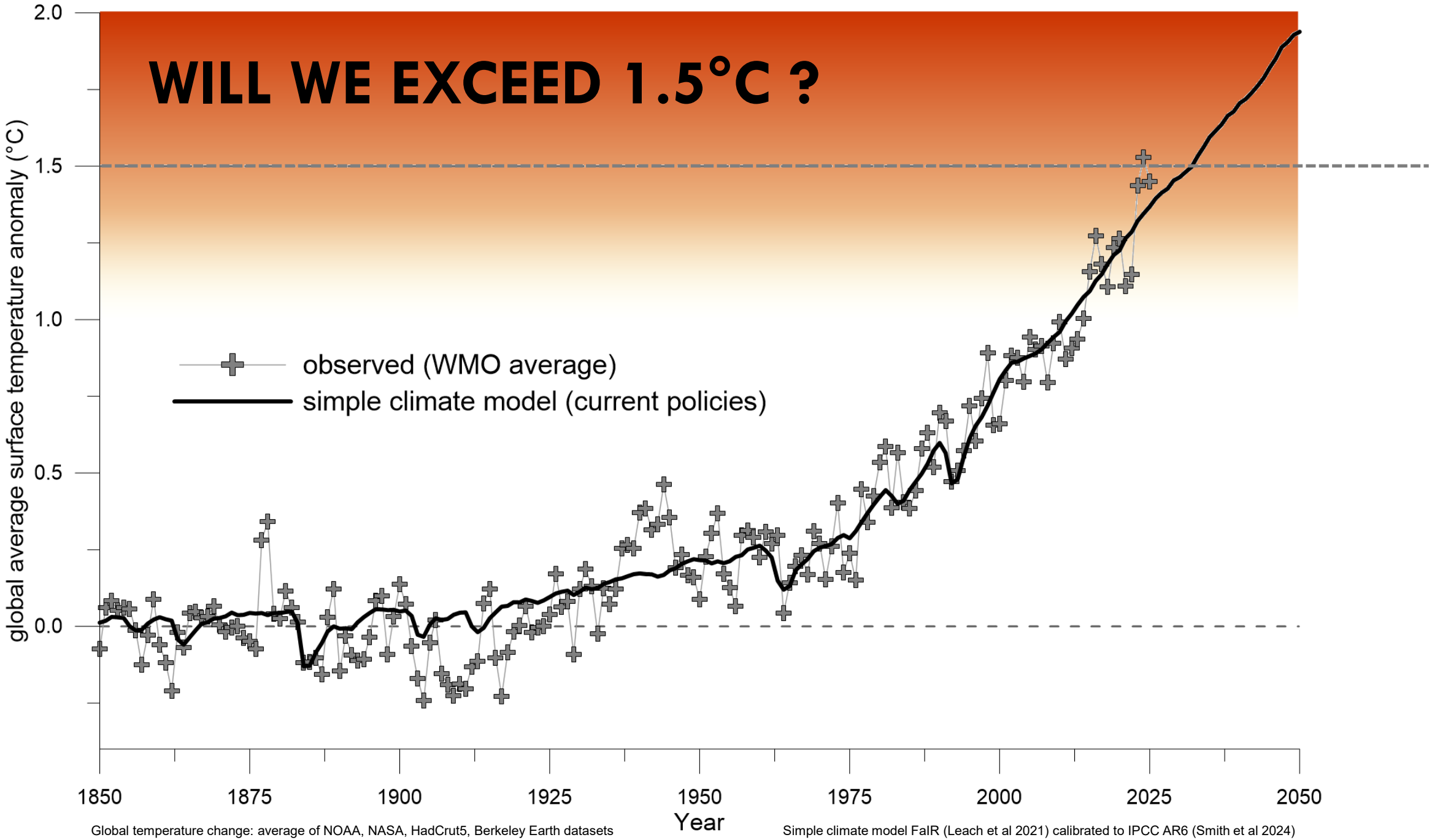
CONTENT

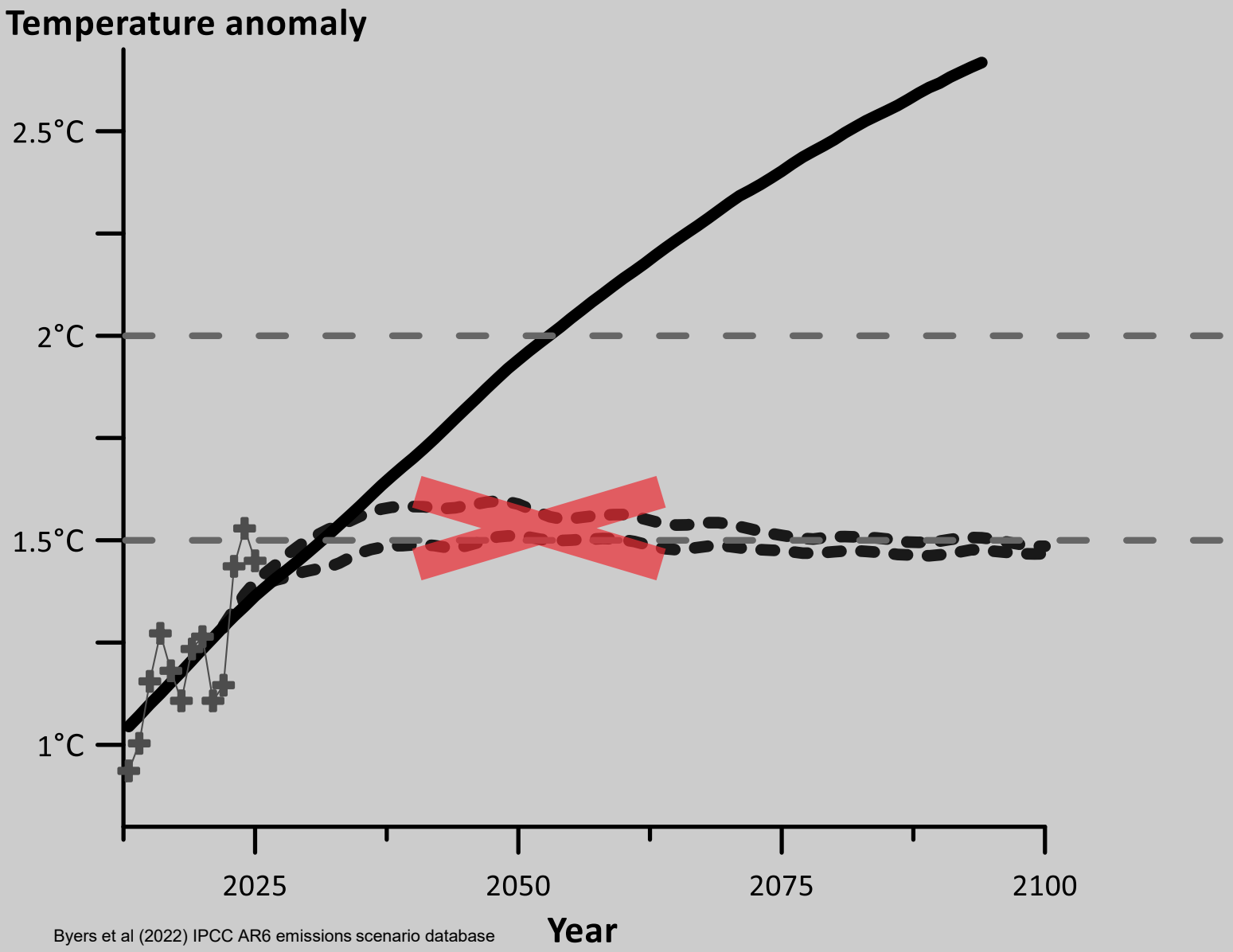
- Will we exceed 1.5°C?
- How did we get there – what now?
- Conditions for a return to 1.5°C
- Risks under overshoot scenarios
- Challenges and choices


WILL WE EXCEED 1.5°C ?
global average surface temperature anomaly (°C)
2.0
1.5
1.0
0.5
0.0
observed (WMO average)
simple climate model (current policies)
1850
1875
1900
1925
1950
1975
2000
2025
2050
Year
Global temperature change: average of NOAA, NASA, HadCrut5, Berkeley Earth datasets
Simple climate model FaIR (Leach et al 2021) calibrated to IPCC AR6 (Smith et al 2024)

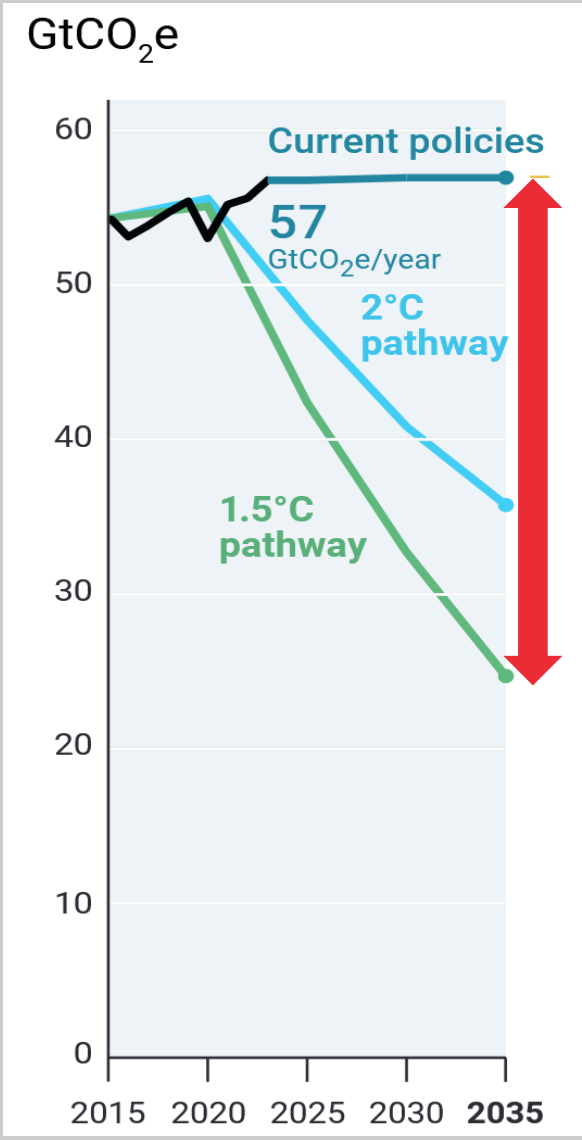

Business as usual
Exit for 1.5°C
slow
down
1
1
Carbon budget
no overshoot 500 Gt
with overshoot 600 Gt
likely below 2°C 850 Gt
about 2°C 1350 Gt
base picture credit: Transport Scotland

base picture credit: csd75/Flickr

WE WILL EXCEED WARMING OF 1.5°C

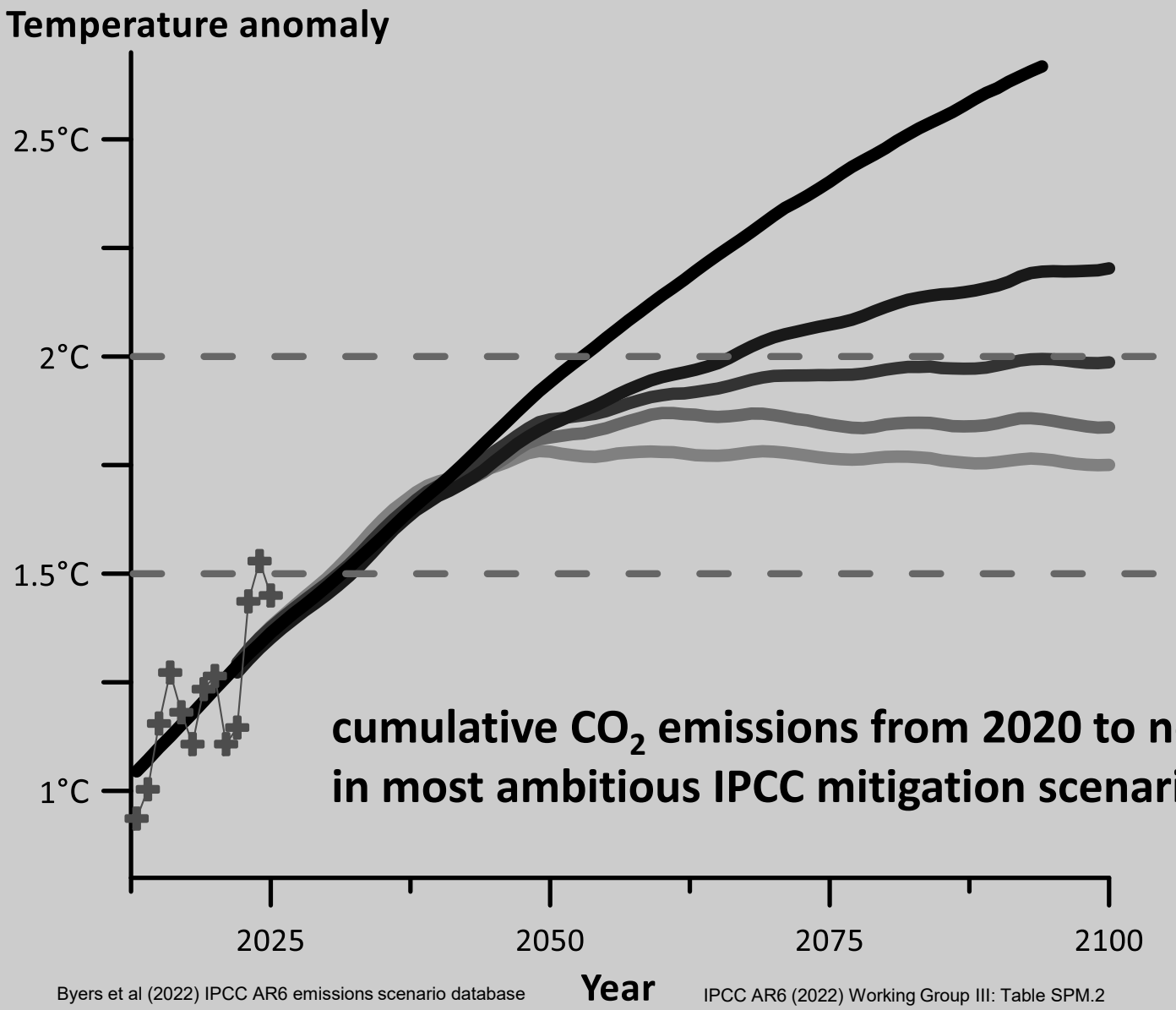


Byers et al (2022) IPCC AR6 emissions scenario database



UNEP (2024) Emissions Gap Report 2024: No more hot air … please!

THE NEXT EXIT: EVERY YEAR, EVERY TONNE MATTERS



Byers et al (2022) IPCC AR6 emissions scenario database

IPCC AR6 (2022) Working Group III: Table SPM.2

Remaining carbon budget

(assuming 42 $GtCO_2$ in 2025; remaining carbon budget from Forster et al (2025) doi: 10.5194/essd-17-2641-2025)

- **from 1 January 2020, for 1.5°C:**

  500 Gt CO_2
- **from 1 January 2026, for 1.6°C:**

  268 Gt CO_2
- **from 1 January 2026, for 1.7°C:**

  448 Gt CO_2

cumulative CO_2 emissions from 2020 to net-zero CO_2 in most ambitious IPCC mitigation scenario category

510 [330-710] Gt CO_2

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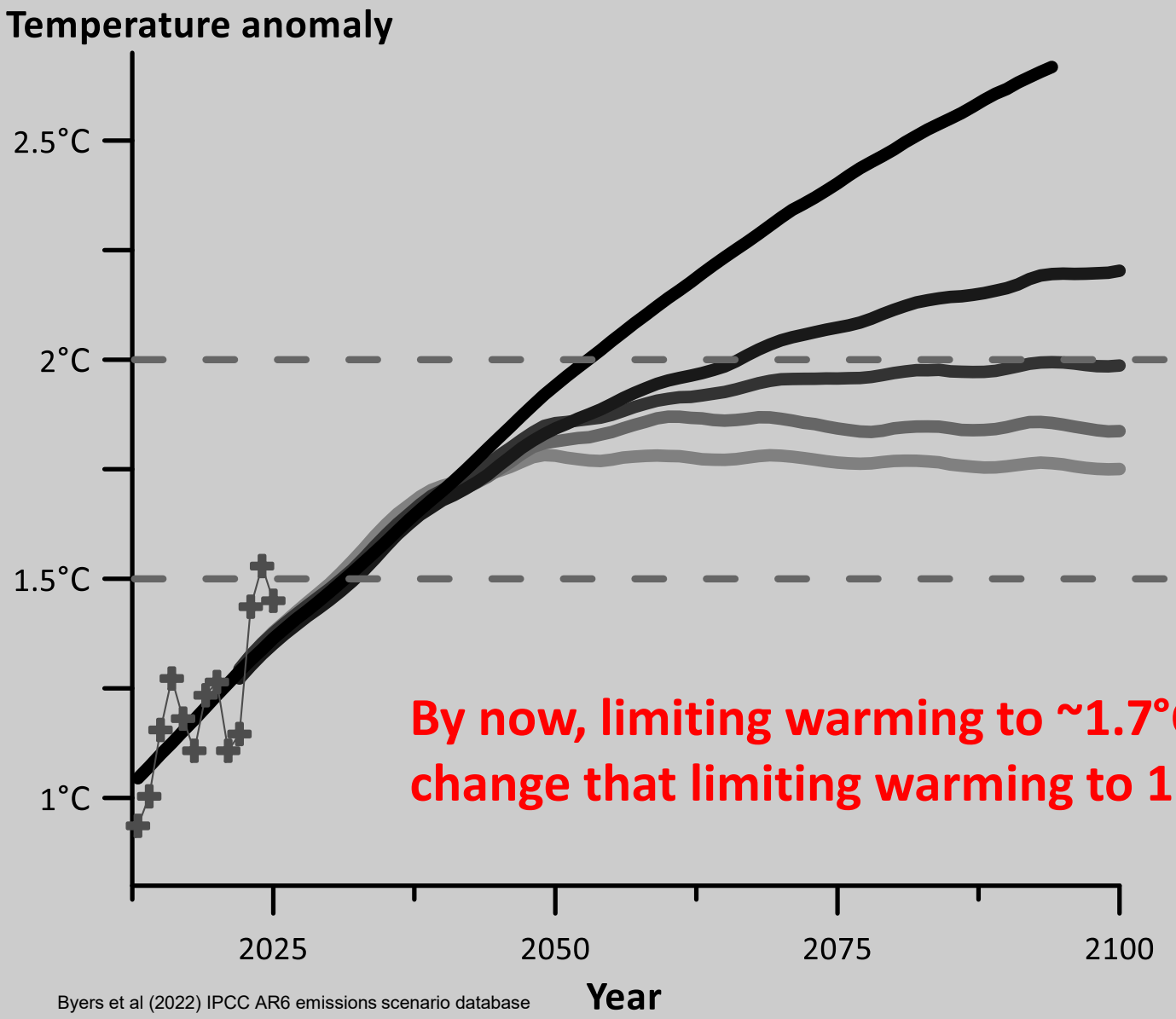
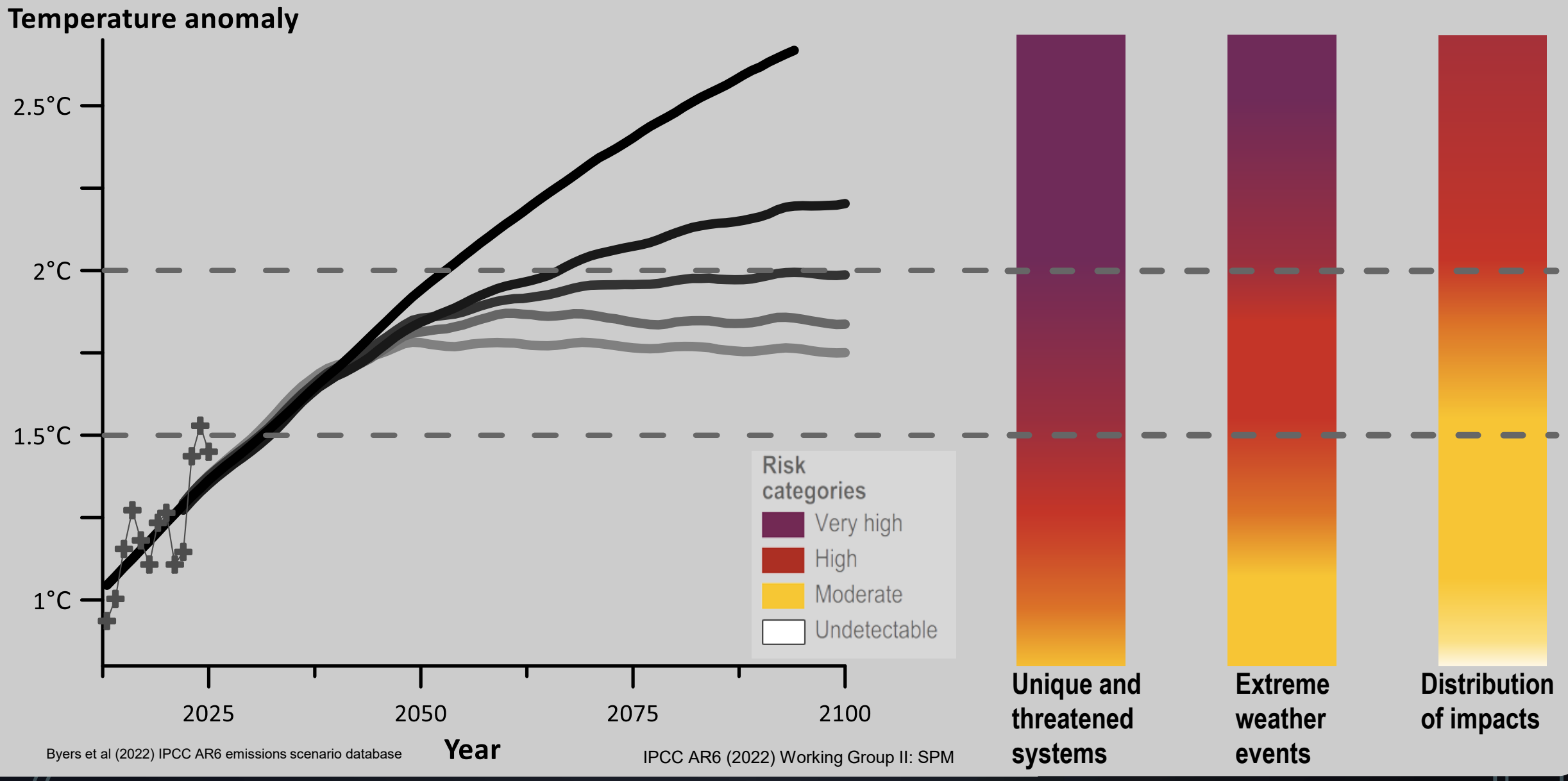


Byers et al (2022) IPCC AR6 emissions scenario database

- global net-zero CO_2 takes ~30 years of *transformational* global action
- during that time, global temperature rises by *at least* another 0.2°C
- every 5 year delay adds another ~0.1°C to global warming

By now, limiting warming to ~1.7°C requires the same transformational change that limiting warming to 1.5°C would have required in 2018-2020

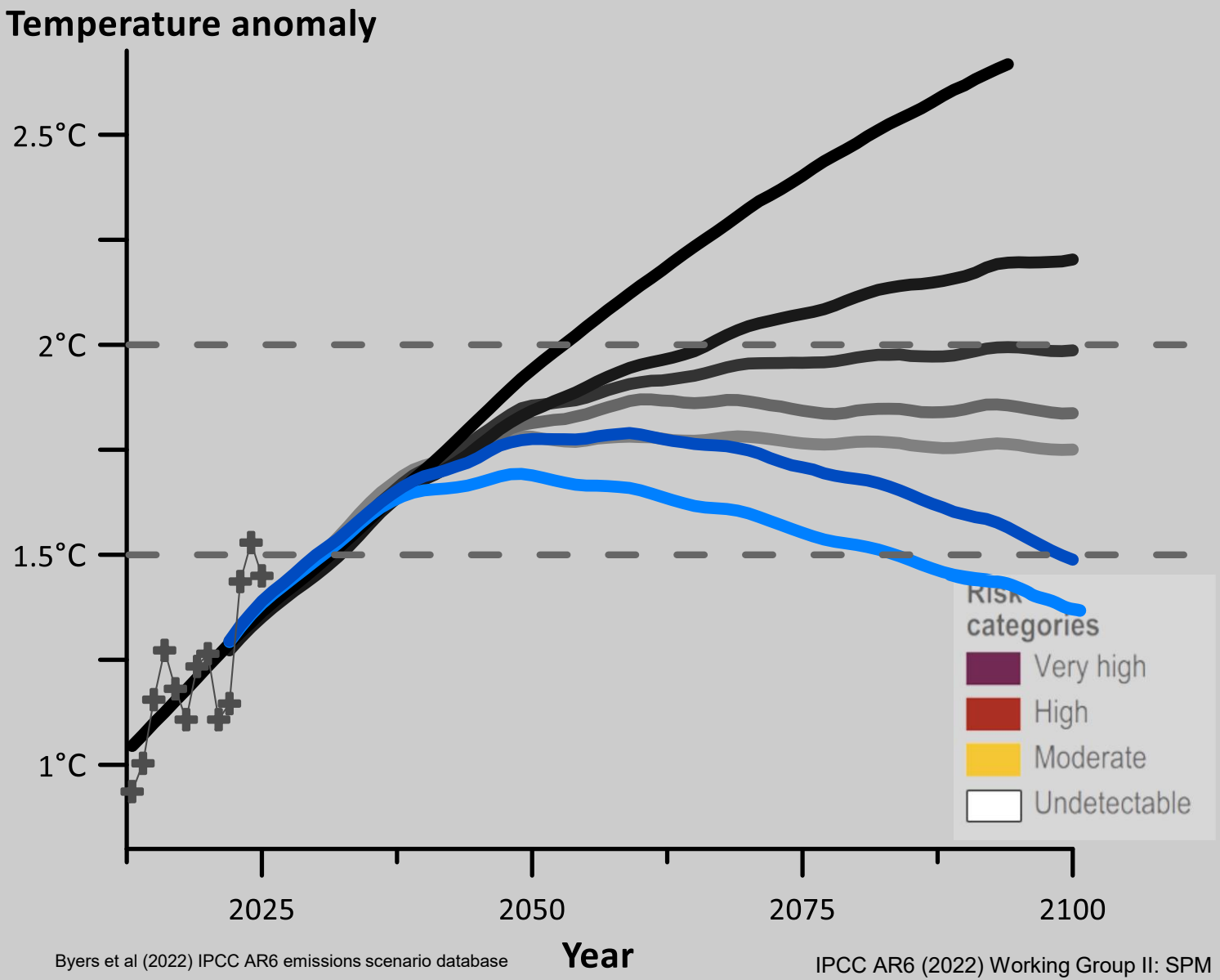
THE NEXT EXIT: EVERY YEAR, EVERY TONNE MATTERS



Byers et al (2022) IPCC AR6 emissions scenario database

IPCC AR6 (2022) Working Group II: SPM

THE LONG WAY HOME



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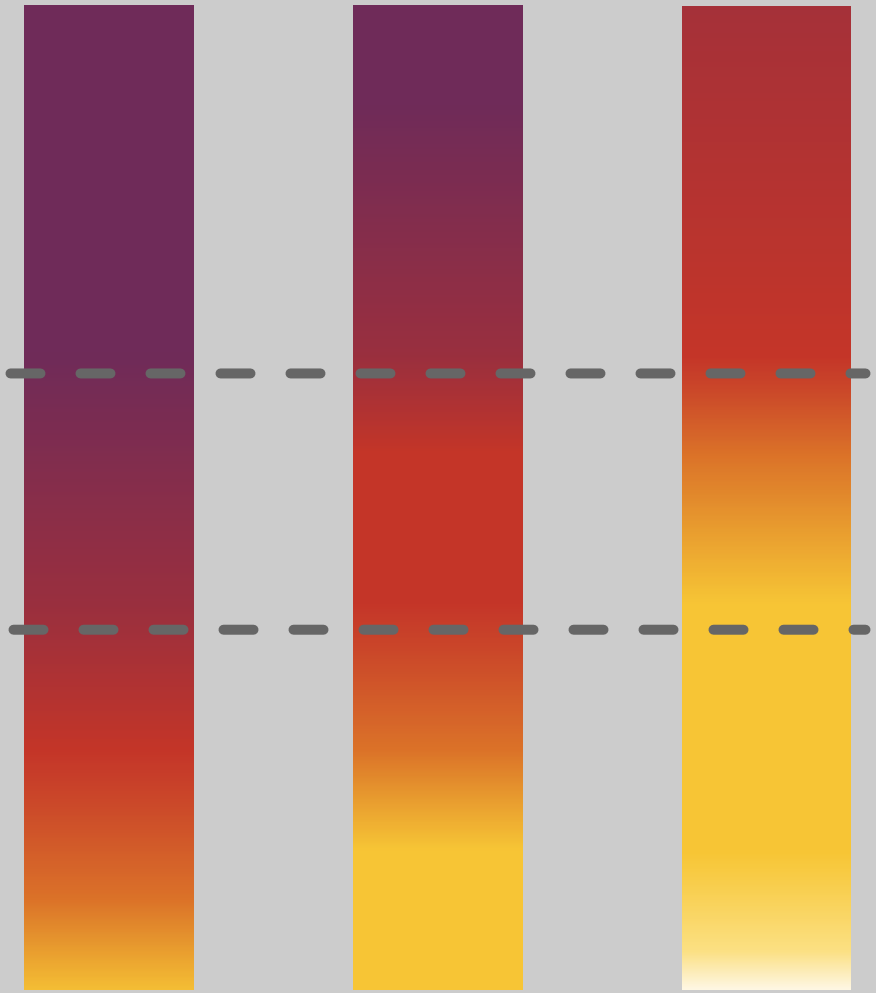

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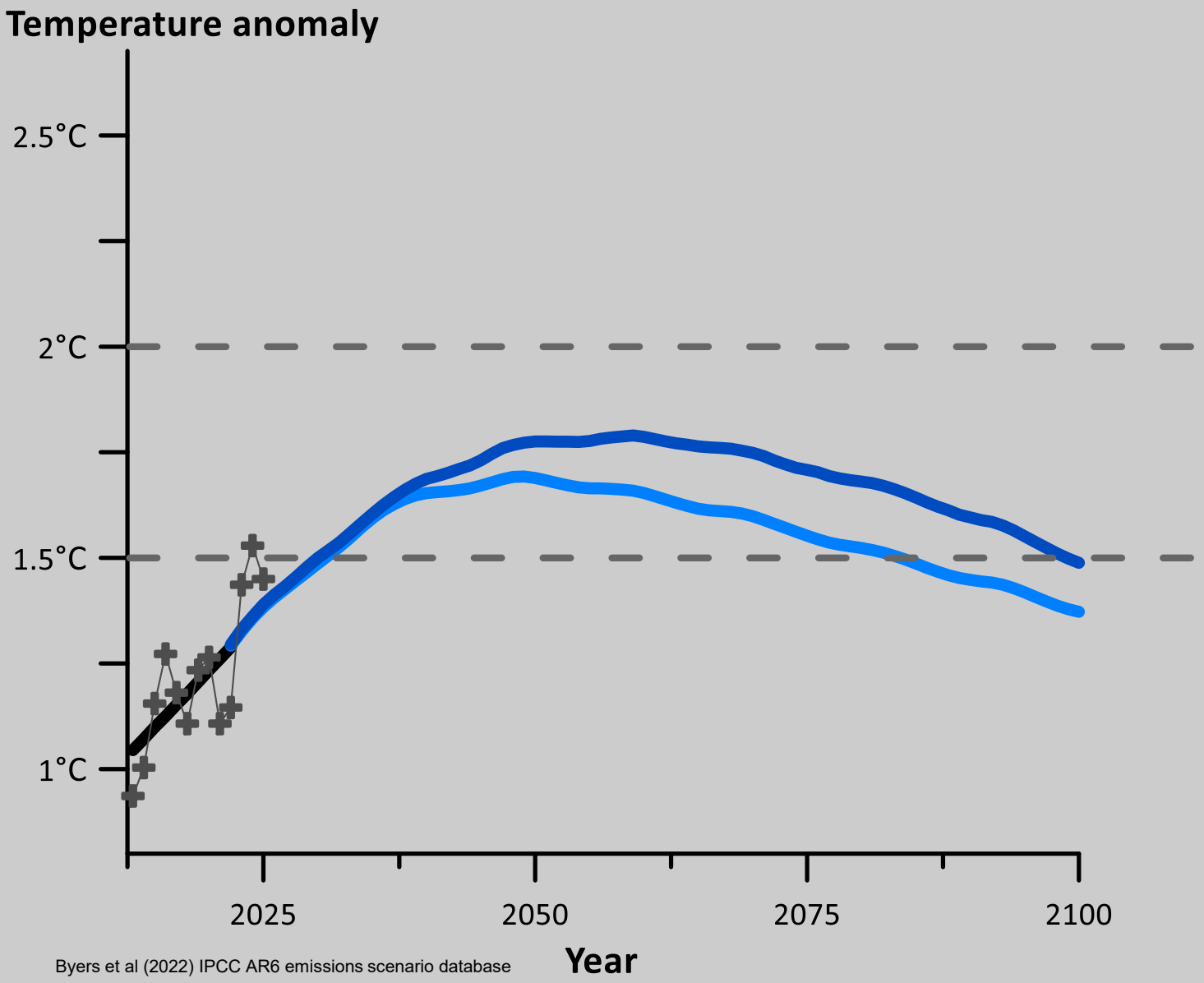


Byers et al (2022) IPCC AR6 emissions scenario database

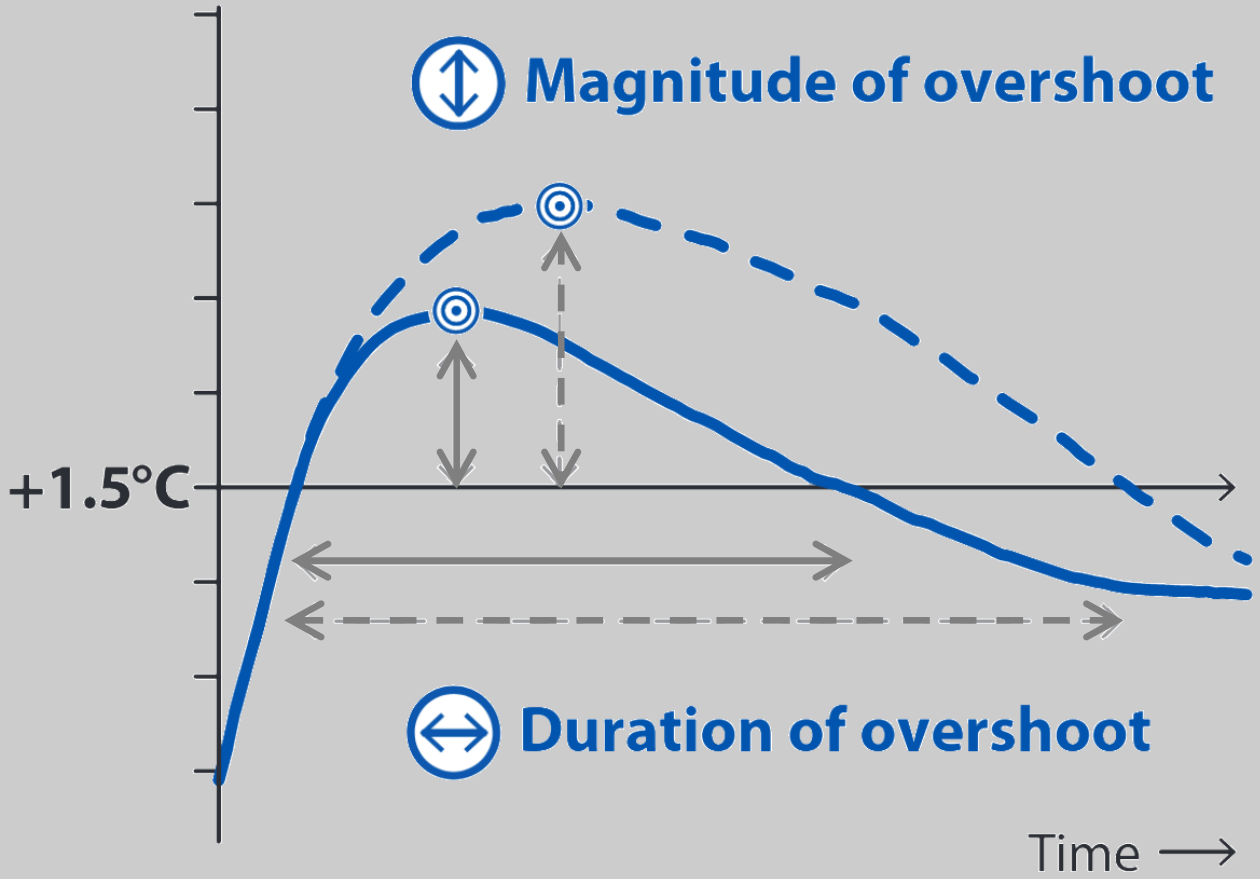
“Overshoot”

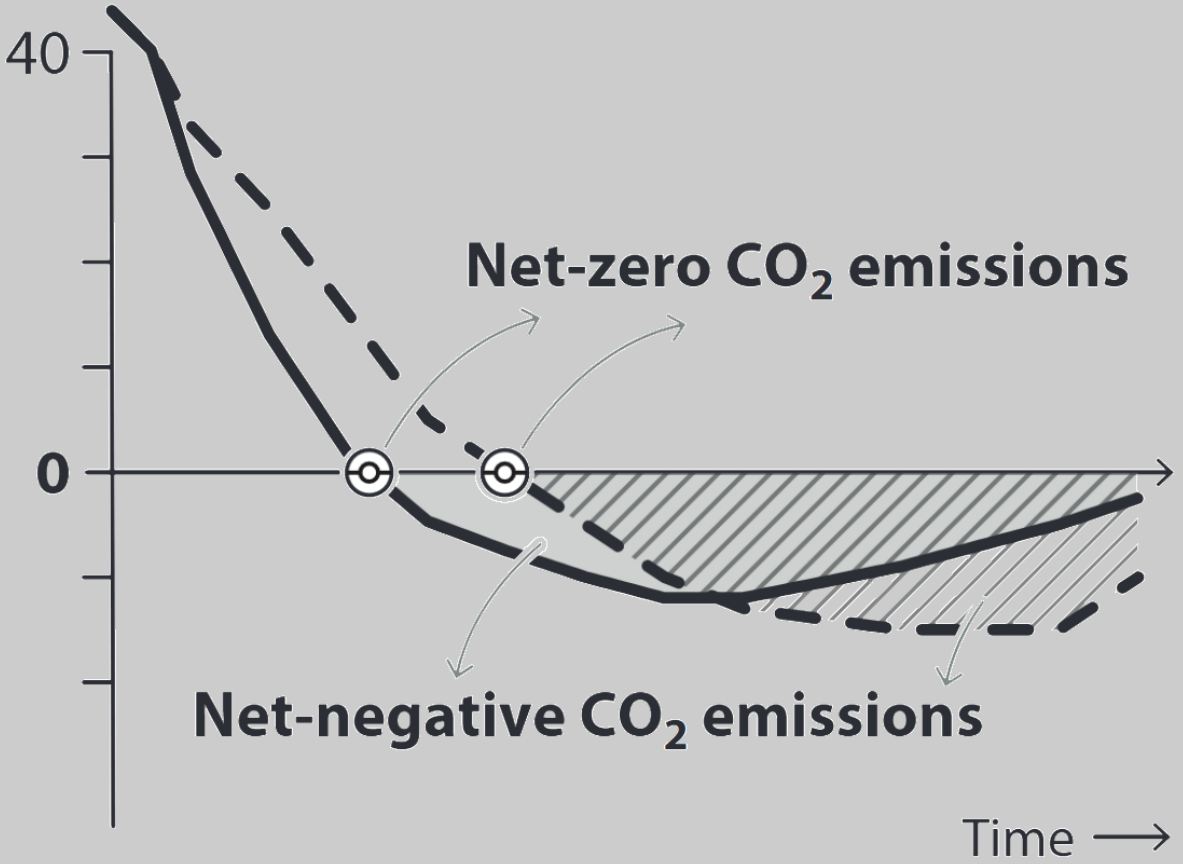
=

exceed <u>and</u> decline

(to a specified warming level)
(within a specified time frame)

THE LONG WAY HOME: EVERY TONNE MATTERS





Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

CONDITIONS FOR A RETURN TO 1.5°C

1. limit magnitude of overshoot:

   reach global net-zero CO_2 as soon as possible
   reduce non-CO_2 emissions as much as possible

2. limit duration of overshoot:

   reduce warming after the peak back to/below 1.5°C:
   net-negative CO_2 emissions and further CH_4 reductions

LIMIT PEAK WARMING AS CLOSE AS POSSIBLE TO 1.5°C

- meet existing targets through robust implementation plans
- increase ambition of NDCs, and of sectoral and domestic targets

POLICY FORUM

CLIMATE POLICY

Credibility gap in net-zero climate targets leaves world at high risk

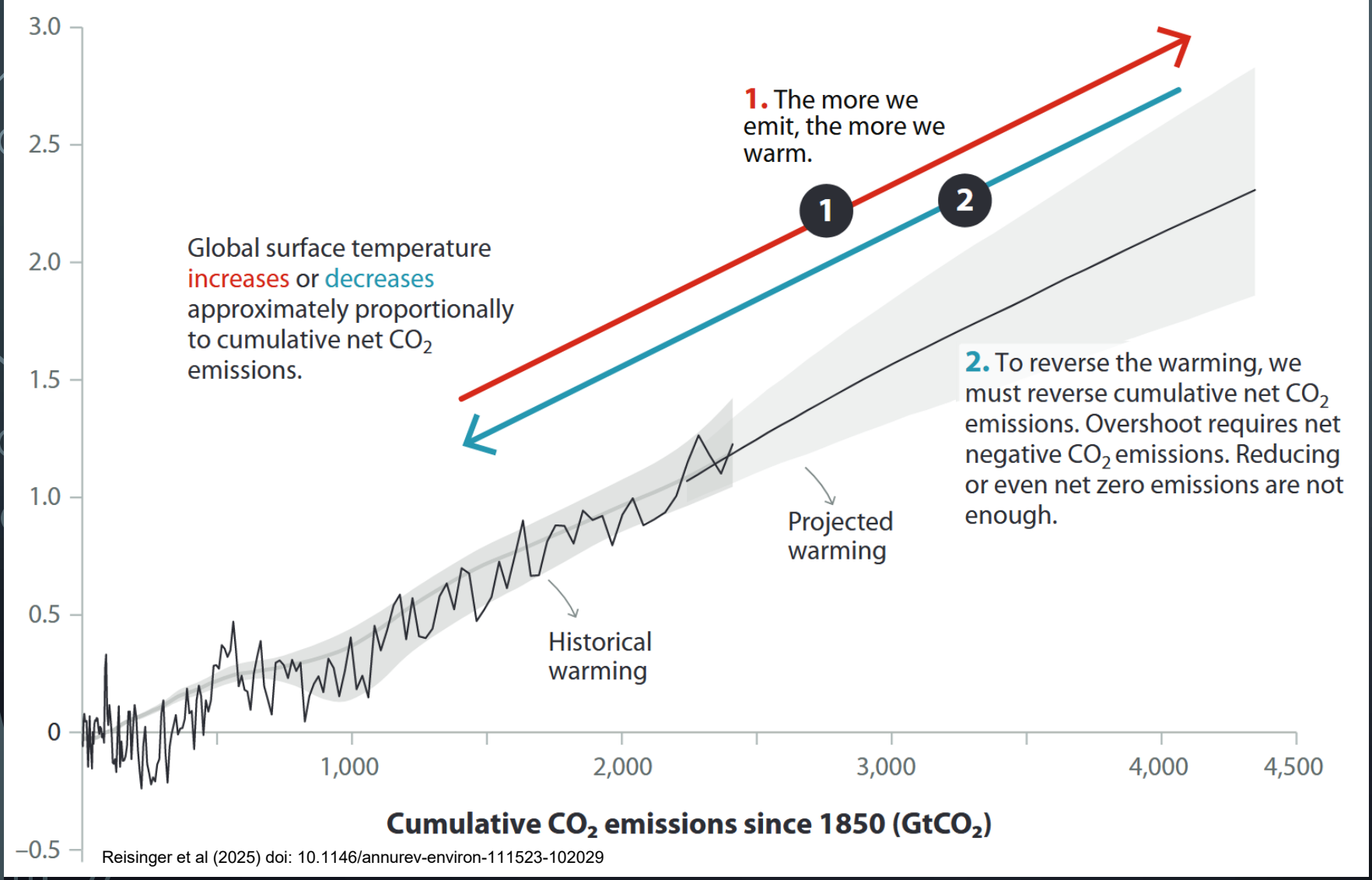
Looking at policies instead of promises shows that global climate targets may be missed by a large margin

By **Joeri Rogelj[1,2,3], Taryn Fransen[4,5], Michel G. J. den Elzen[6,7], Robin D. Lamboll[1], Clea Schumer[4], Takeshi Kuramochi[8,9], Frederic Hans[8], Silke Mooldijk[8], Joana Portugal-Pereira[10]**

pledge actions and emissions reductions that are to be achieved over the next decade (known as nationally determined contributions, or NDCs, currently targeting 2030) and long-term strategies toward net-zero

Rogelj et al (2023) doi: 10.1126/science.adg6248

(PREPARE TO) REDUCE WARMING AFTER THE PEAK

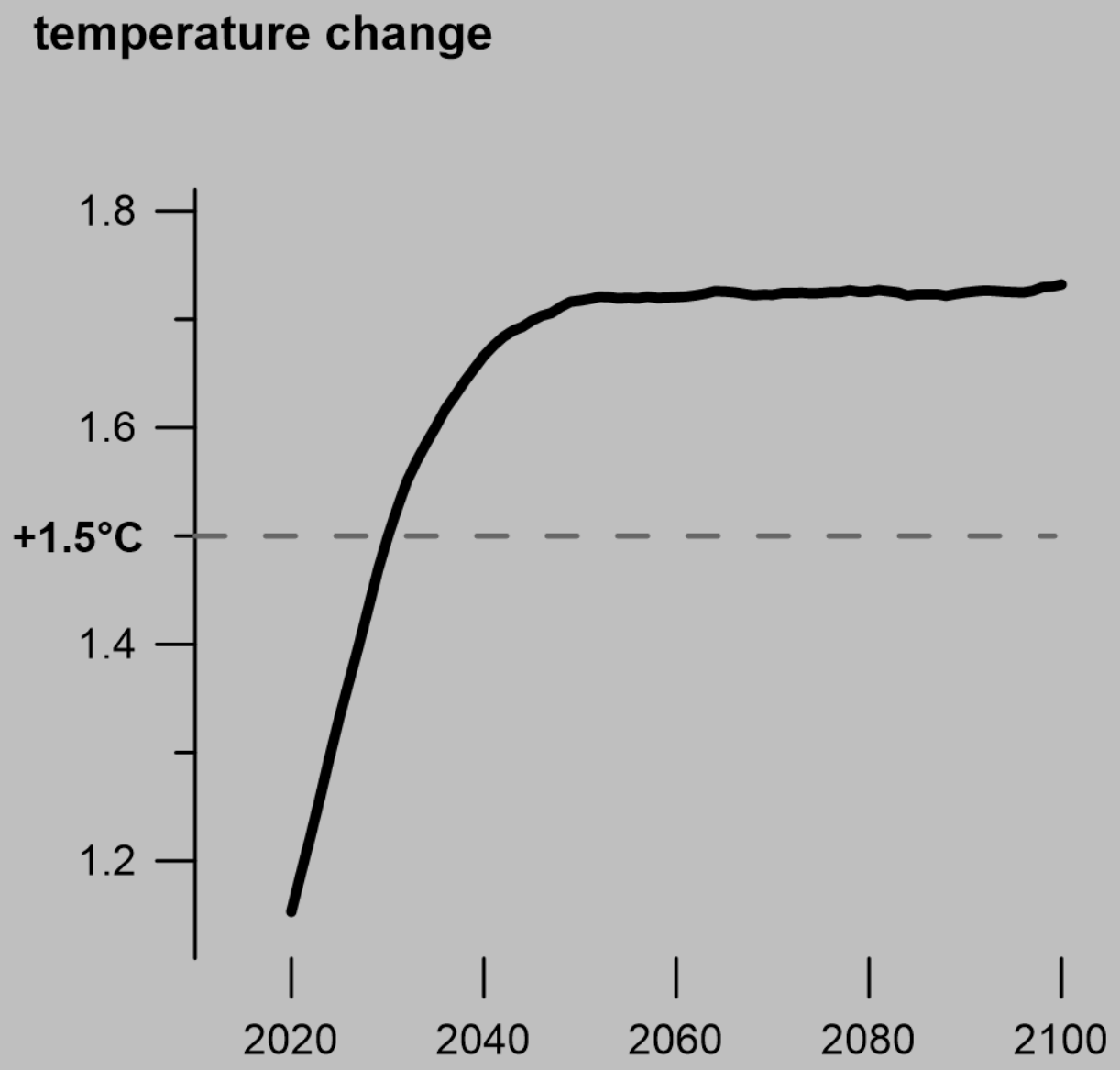


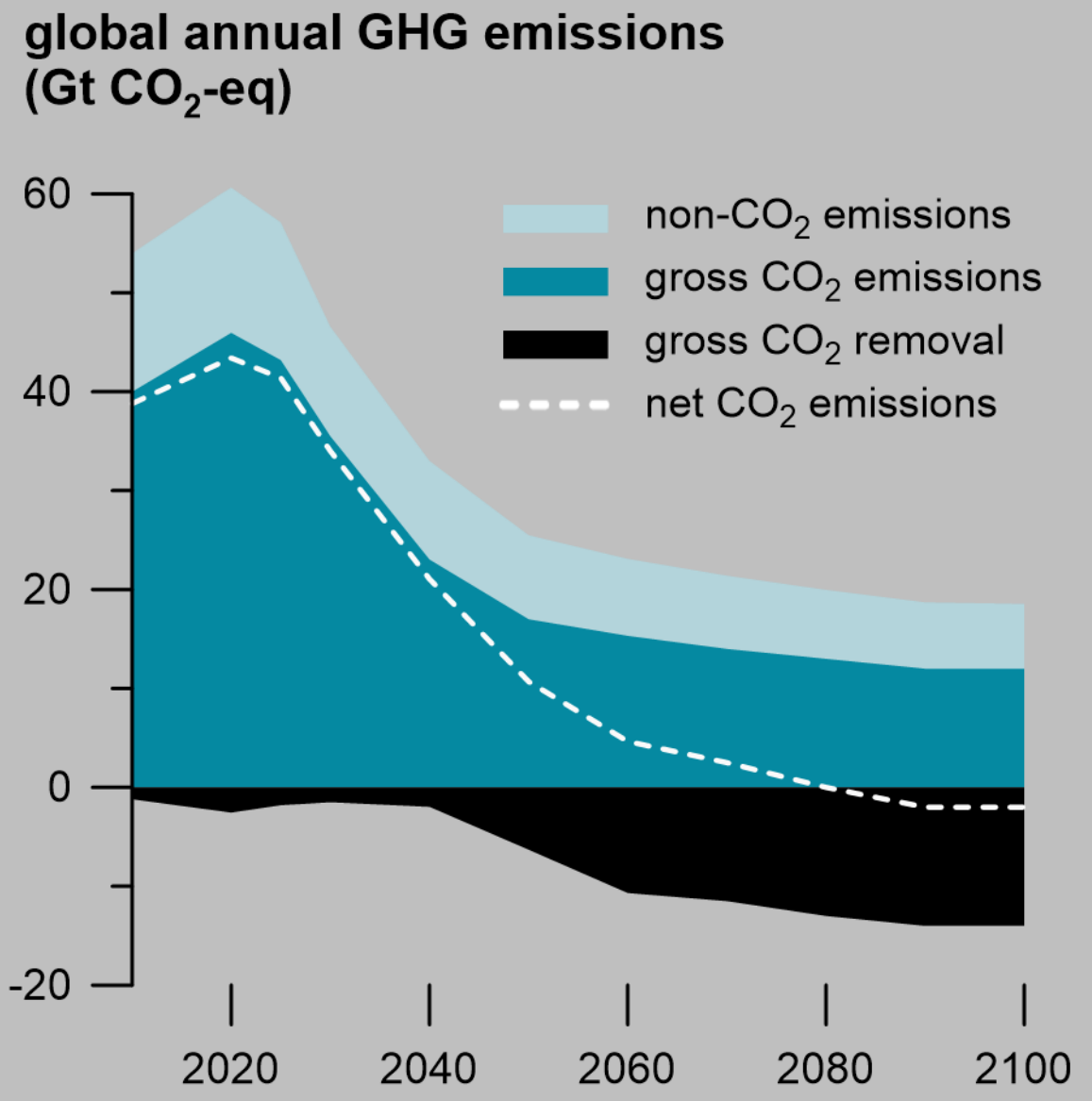
Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

Net-negative CO_2 emissions

& further CH_4 reductions

CLIMATE STABILIZATION PATHWAY





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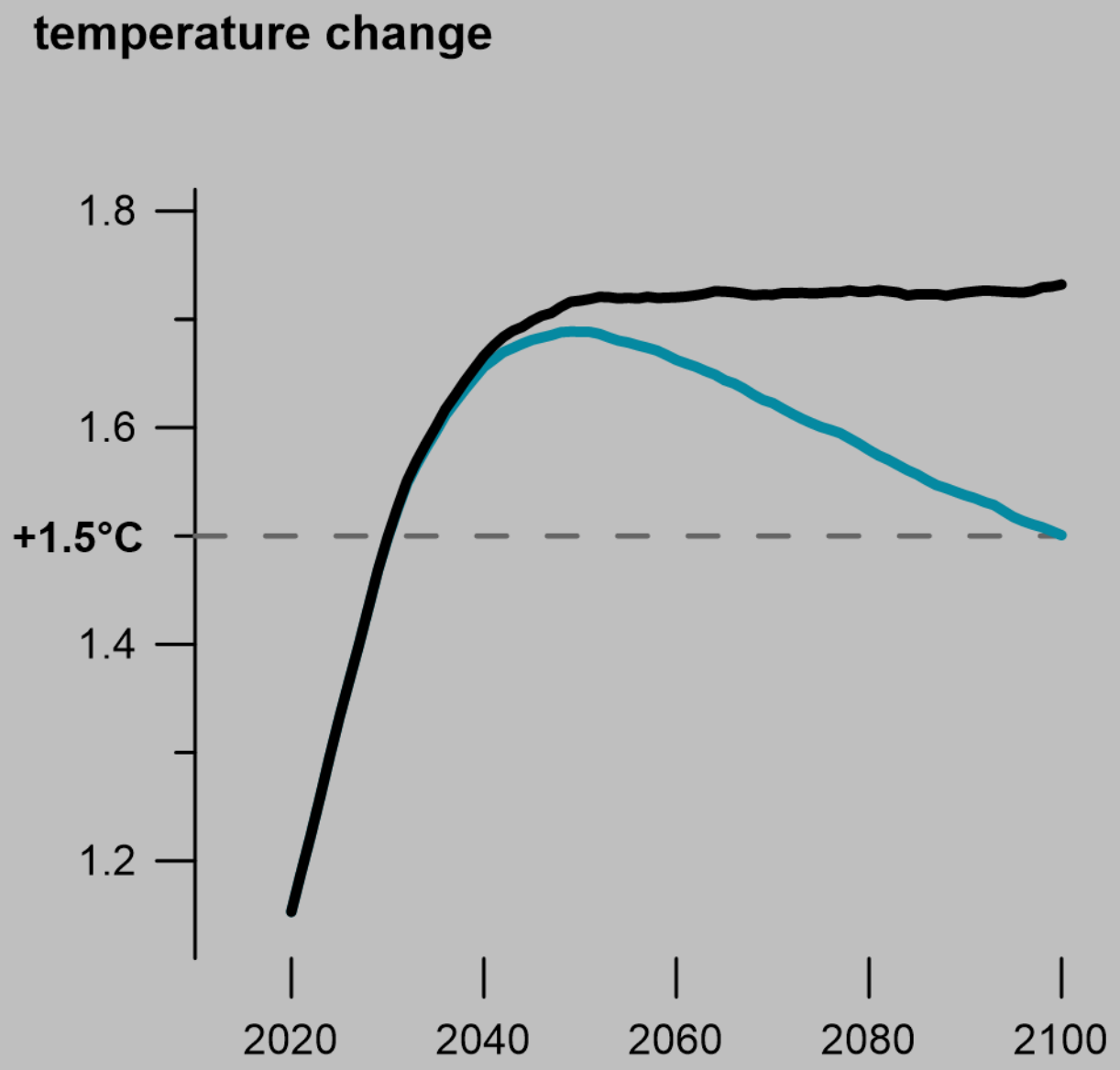
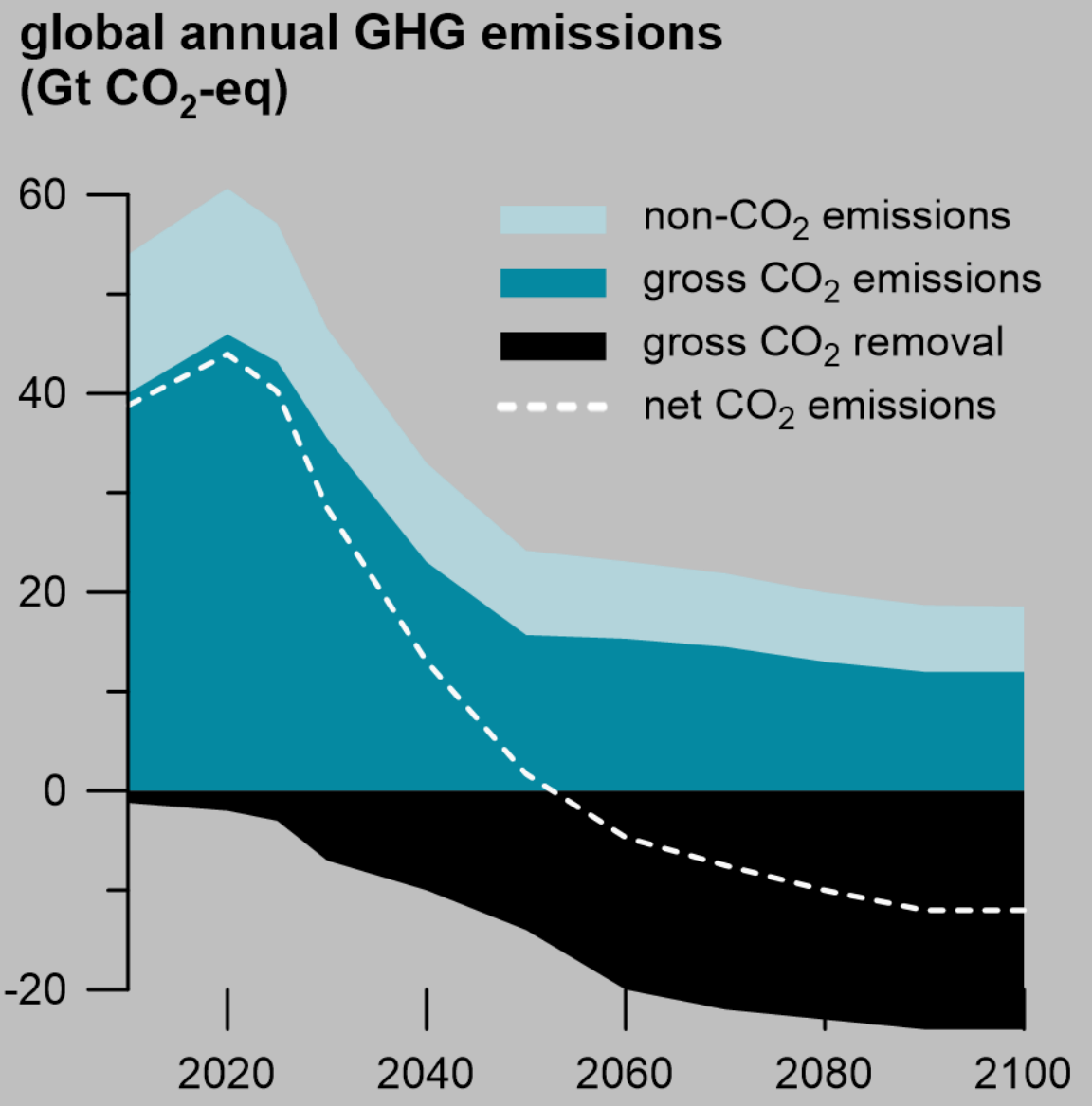
ILLUSTRATIVE OVERSHOOT PATHWAY: CDR





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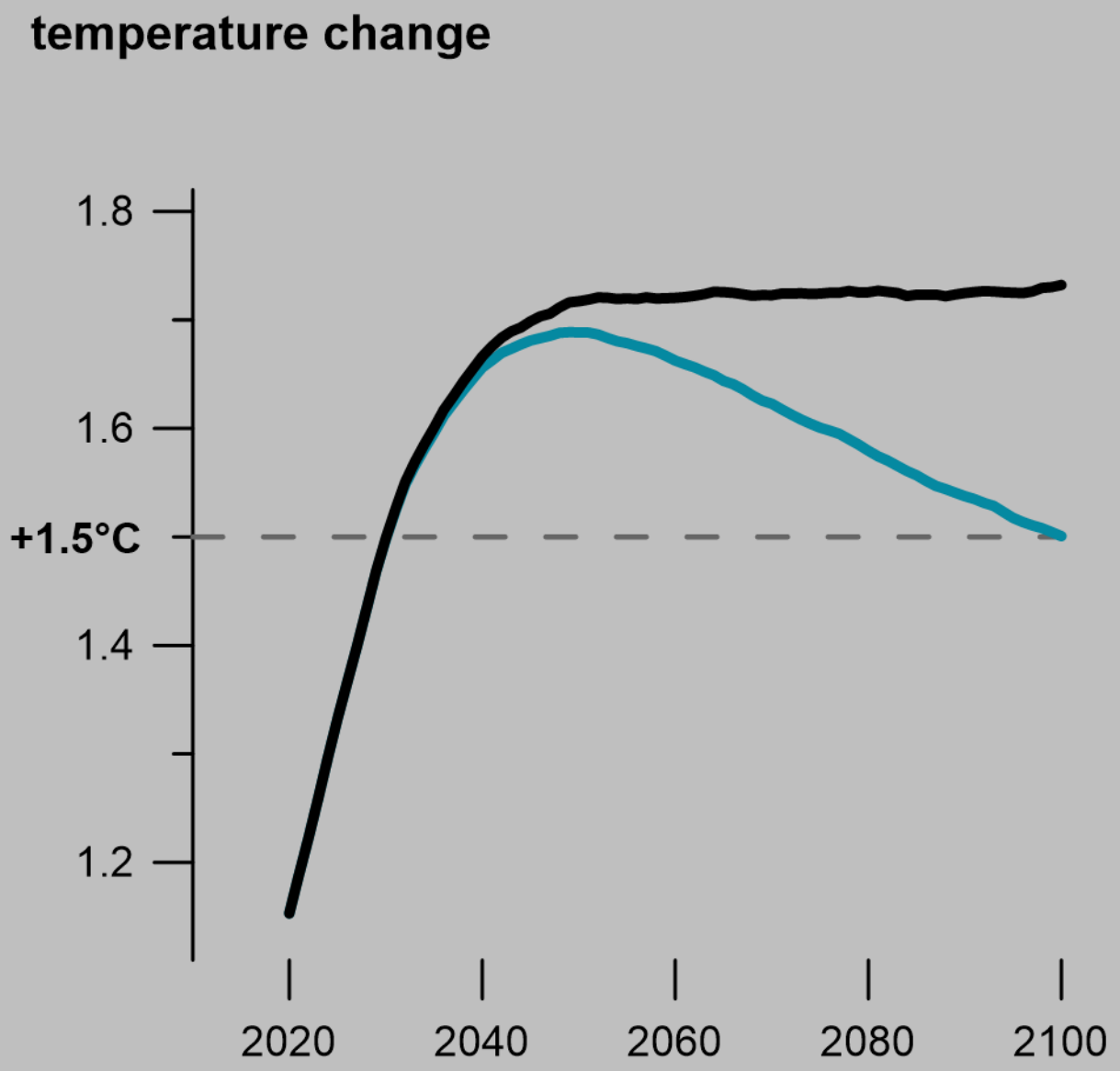
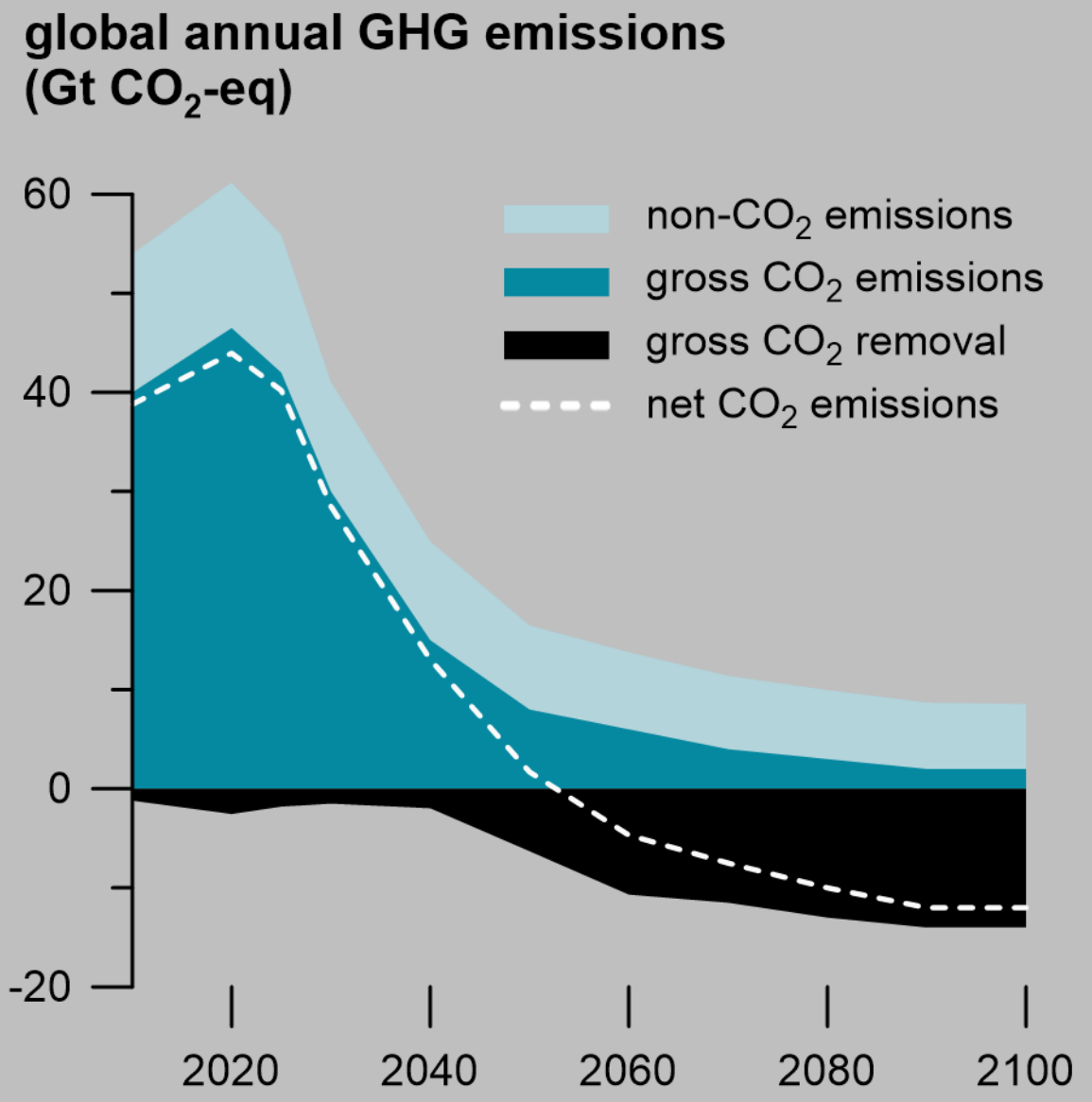
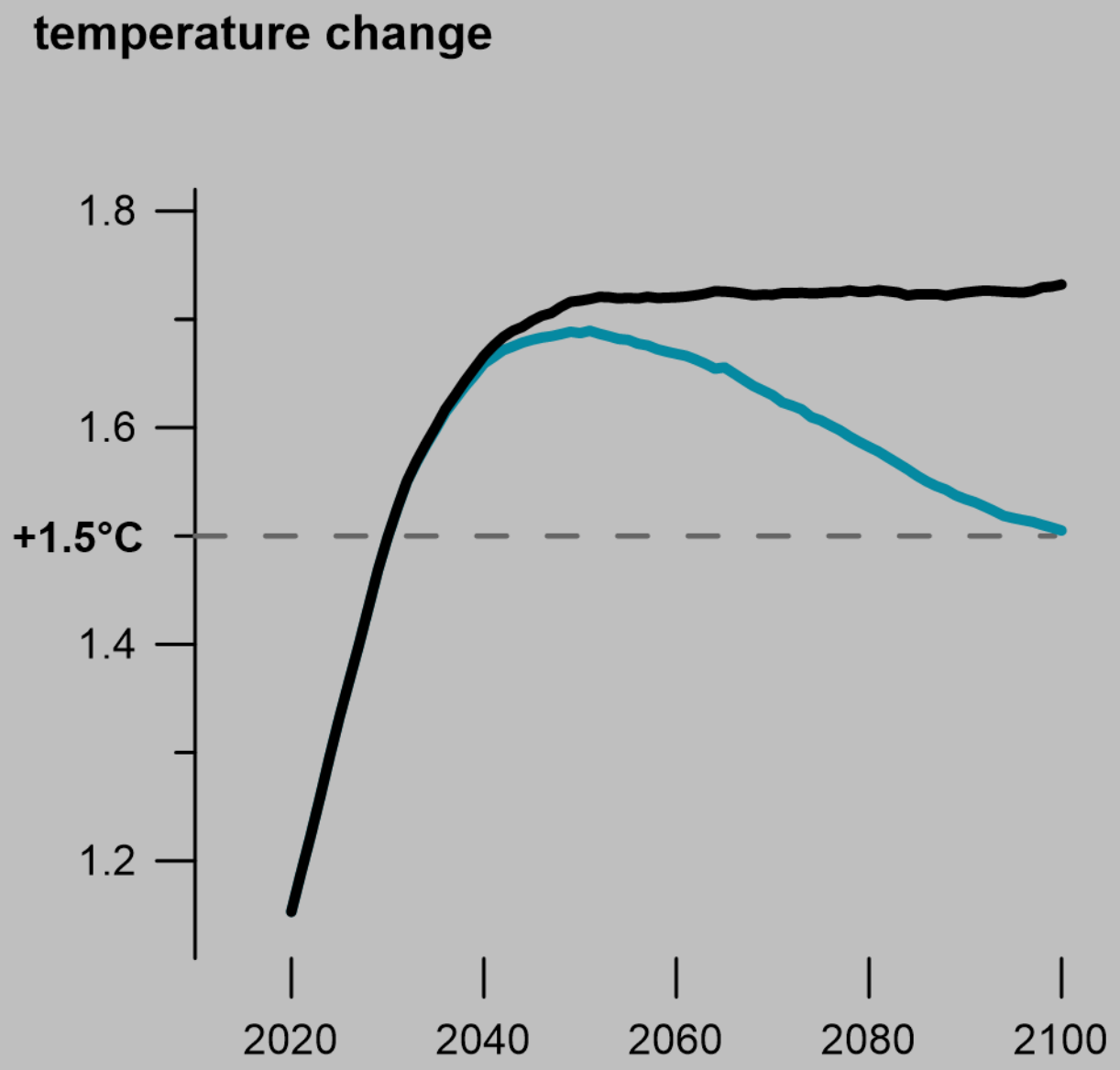
ILLUSTRATIVE OVERSHOOT PATHWAY: gross CO_2

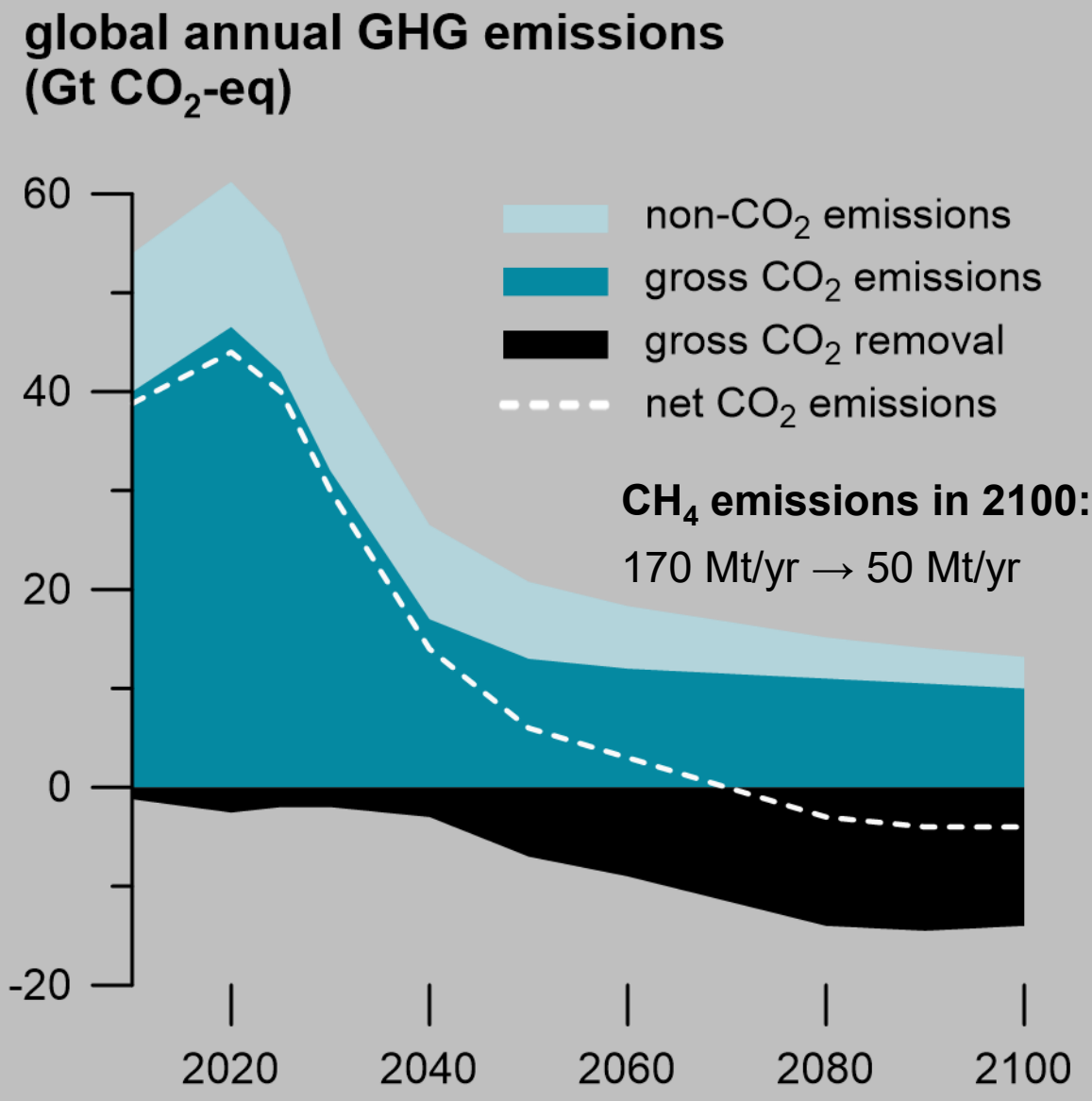




Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

ILLUSTRATIVE OVERSHOOT PATHWAY: gross CH_4





(PREPARE TO) REDUCE WARMING AFTER THE PEAK

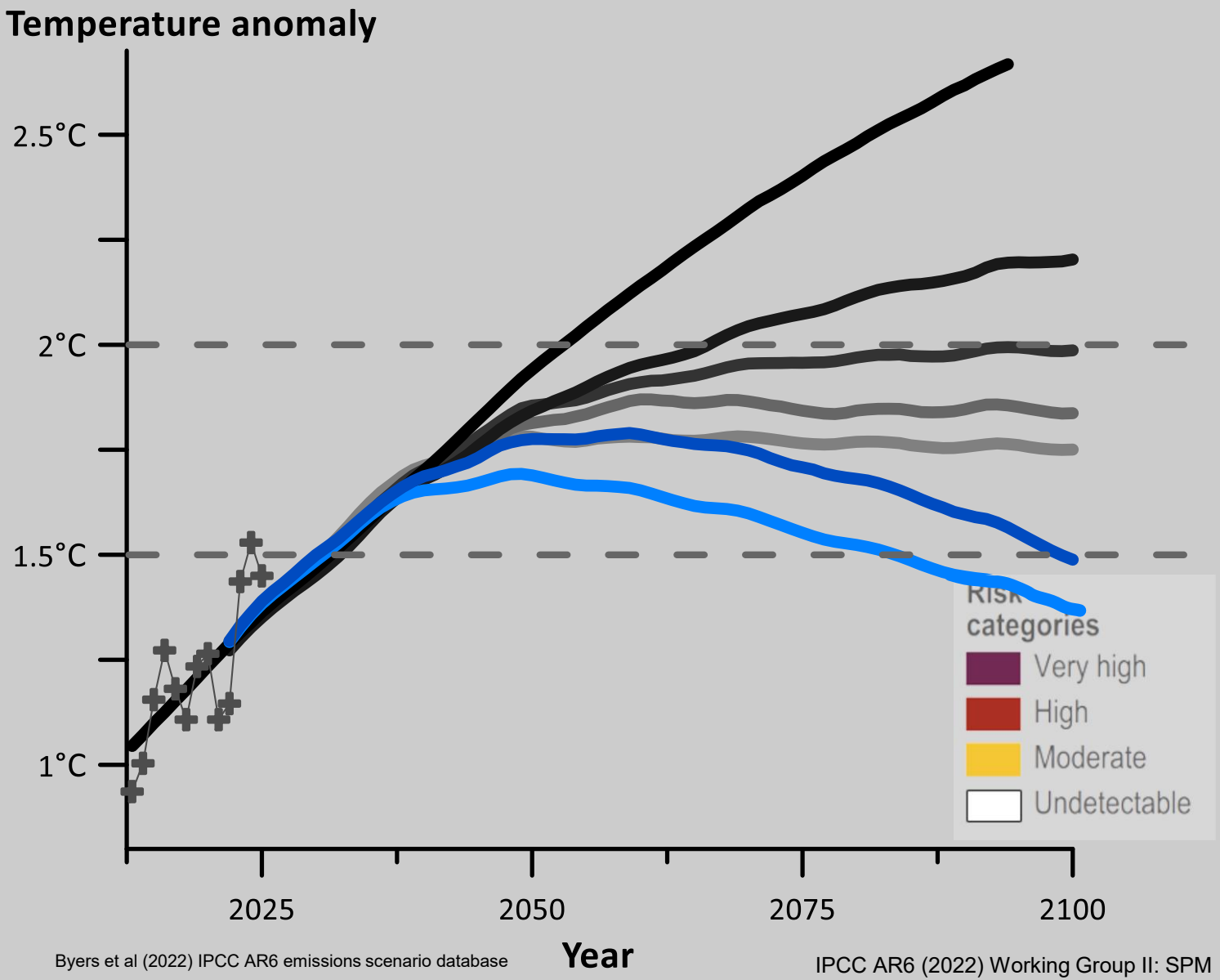
Reducing temperature by 0.1°C after the peak requires:

~ 220 Gt cumulative net-negative CO_2 emissions

~ further 60-70 Mt sustained reduction of CH_4 emissions

- beyond what's necessary already to halt (stabilise) global warming below 2°C

RETURN ≠ RECOVERY



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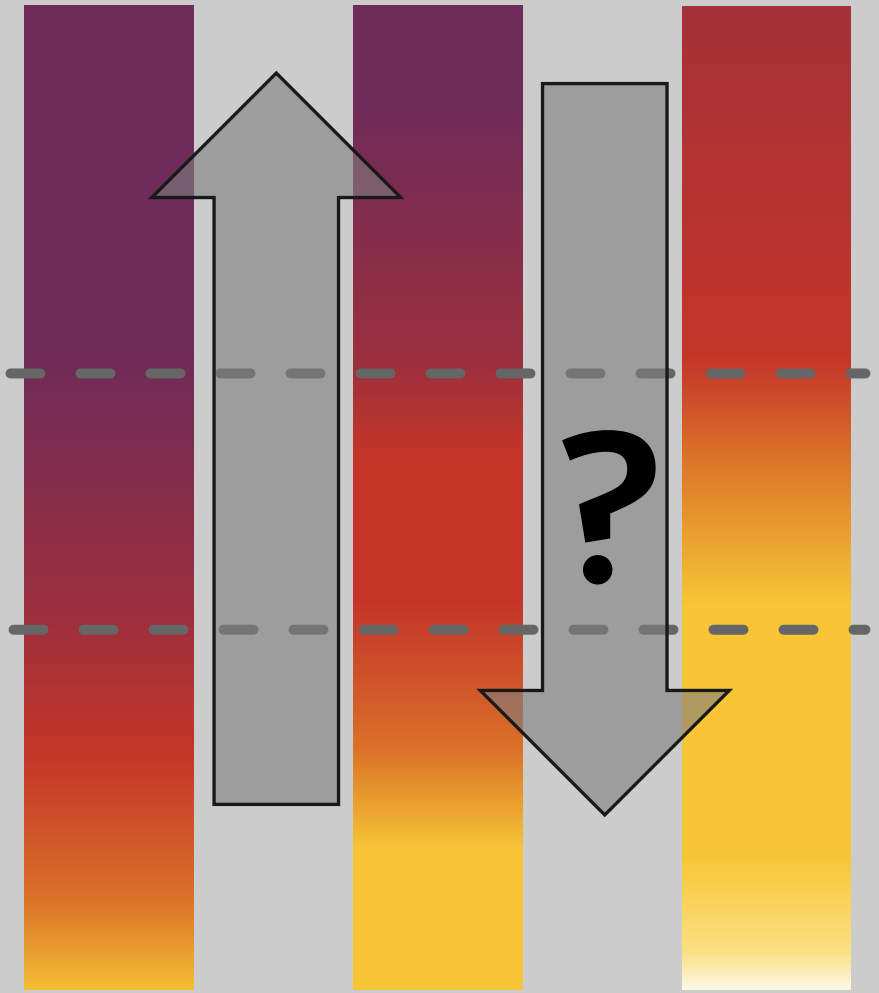
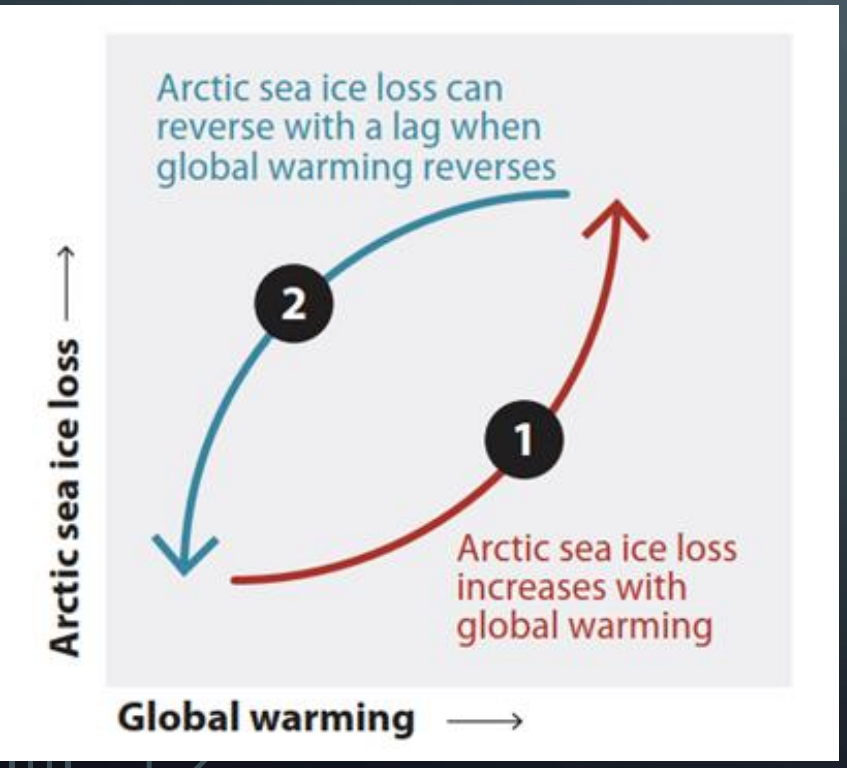
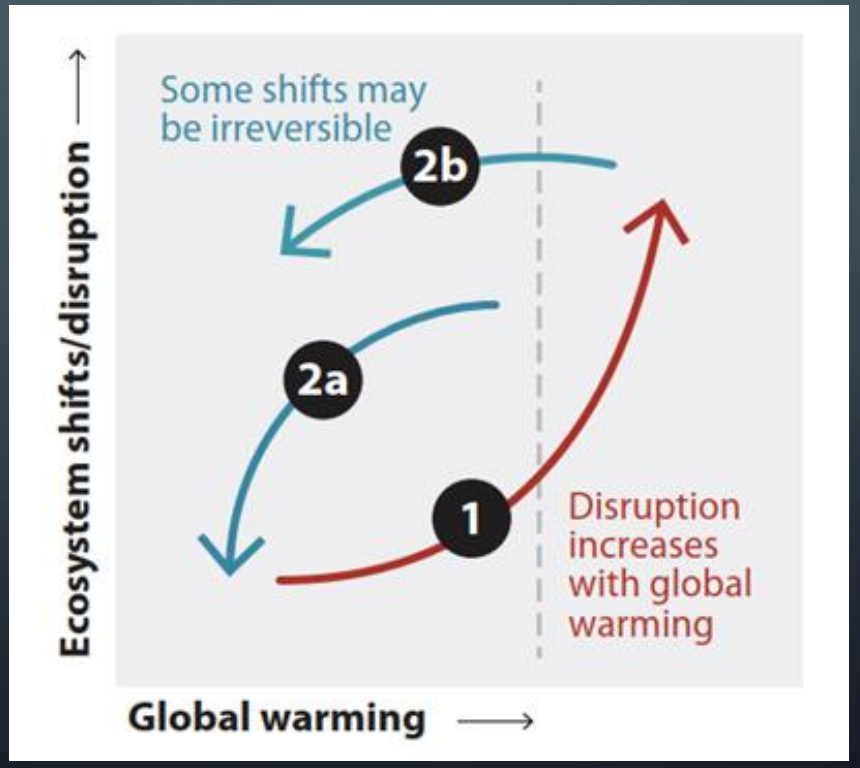


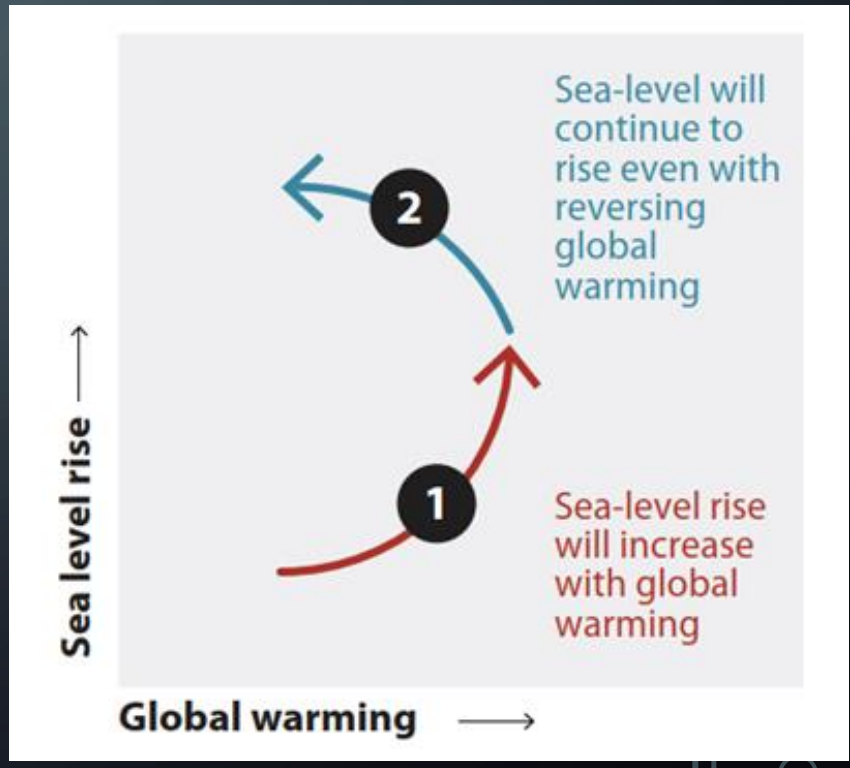
IPCC AR6 (2022) Working Group II: SPM

RETURN ≠ RECOVERY

A reversal of global temperature would not reverse all bio-geo-physical Earth system changes





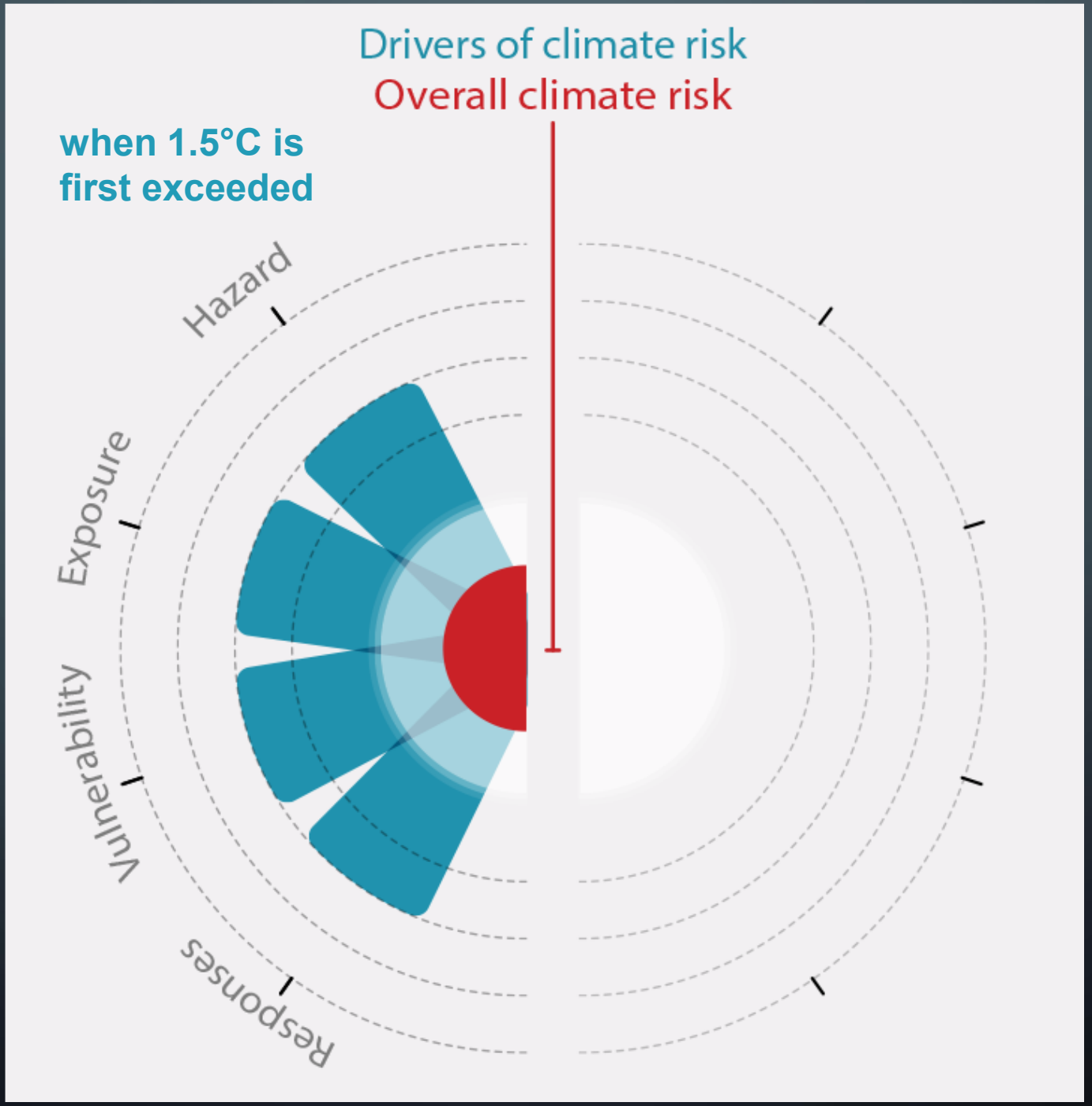


Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

EVOLUTION OF RISK UNDER OVERSHOOT

Simpson et al (2025) doi: 10.1016/j.oneear.2021.03.005

Example: Malnutrition and rural poverty due to drought



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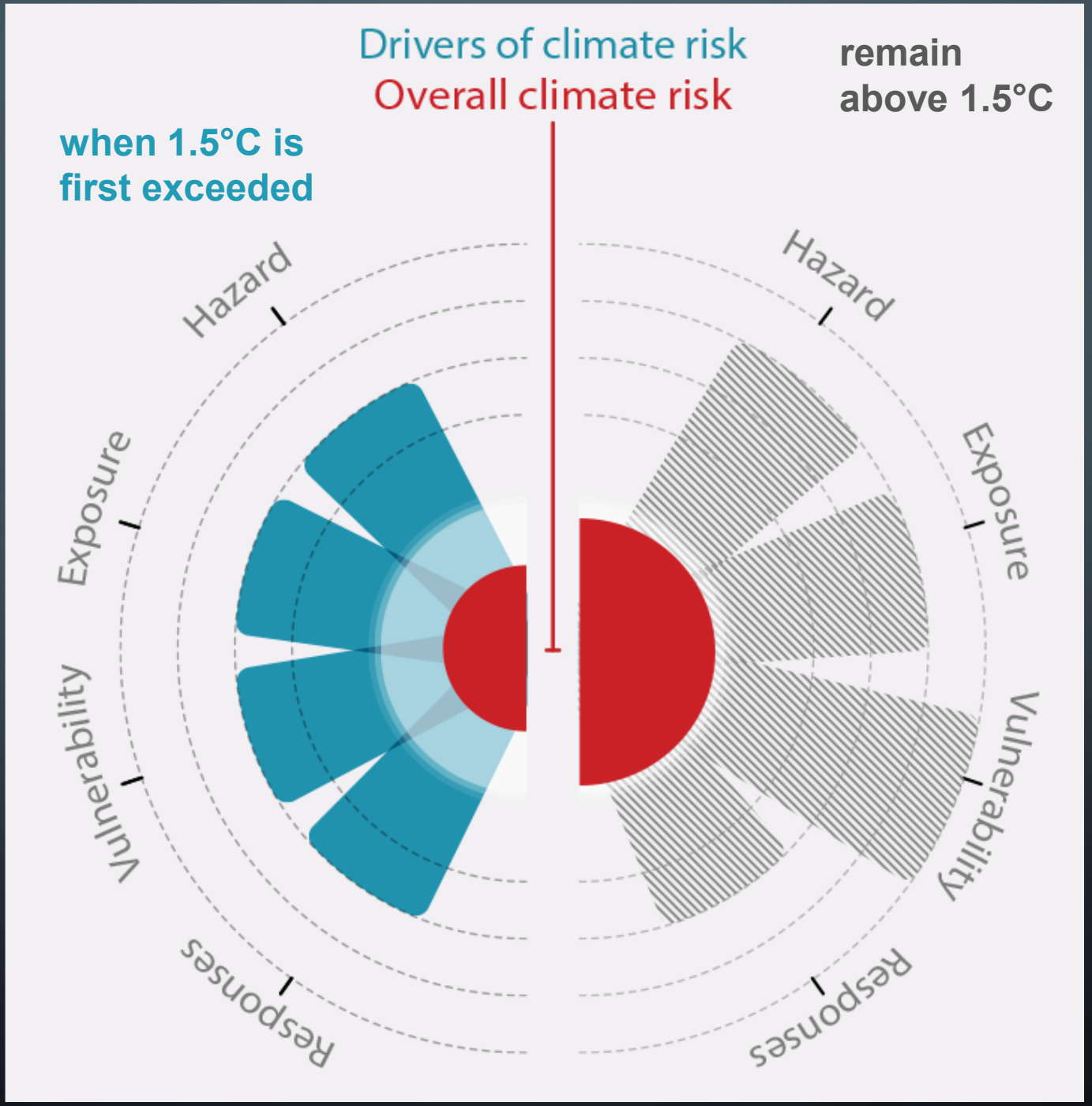

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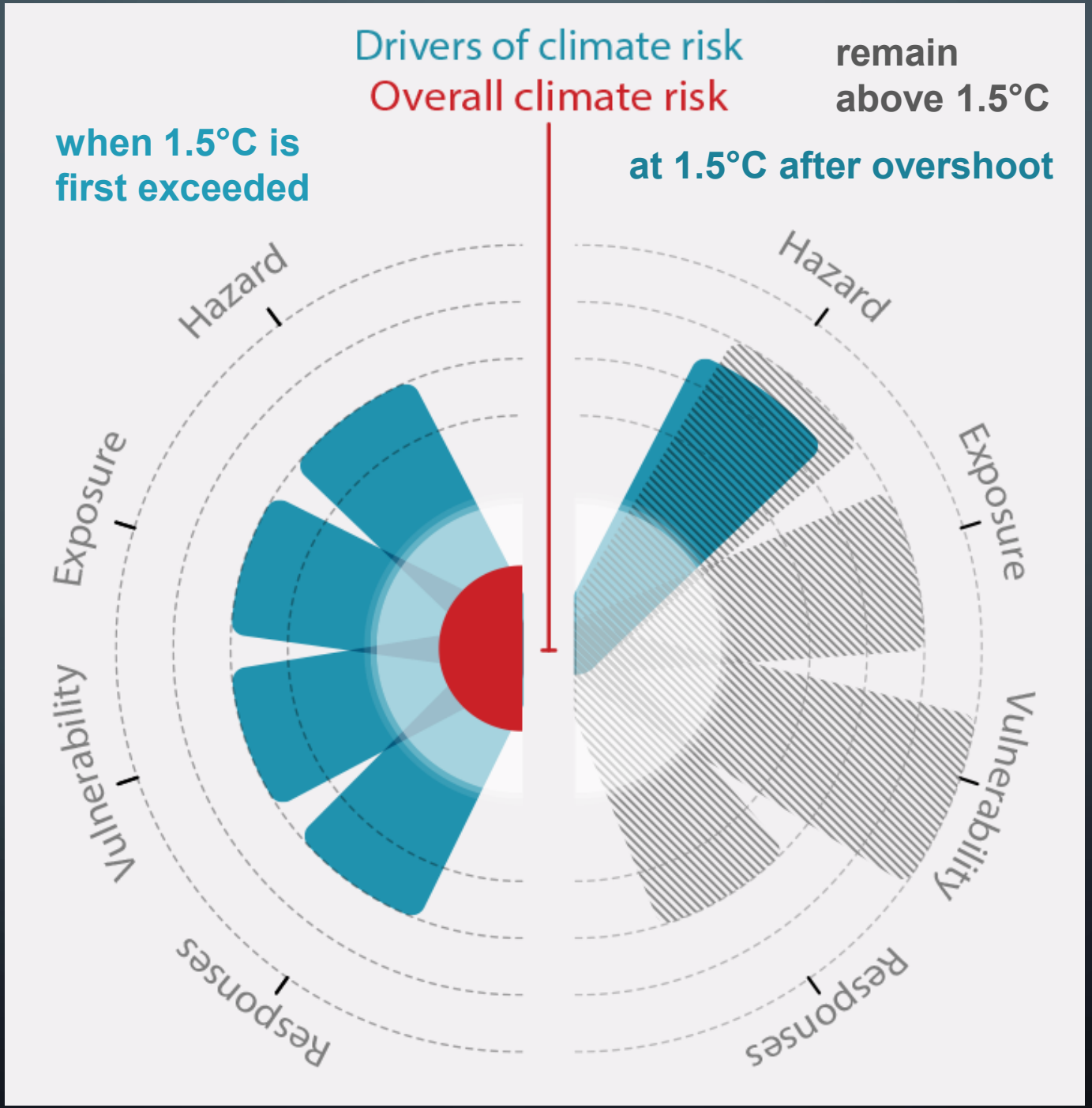

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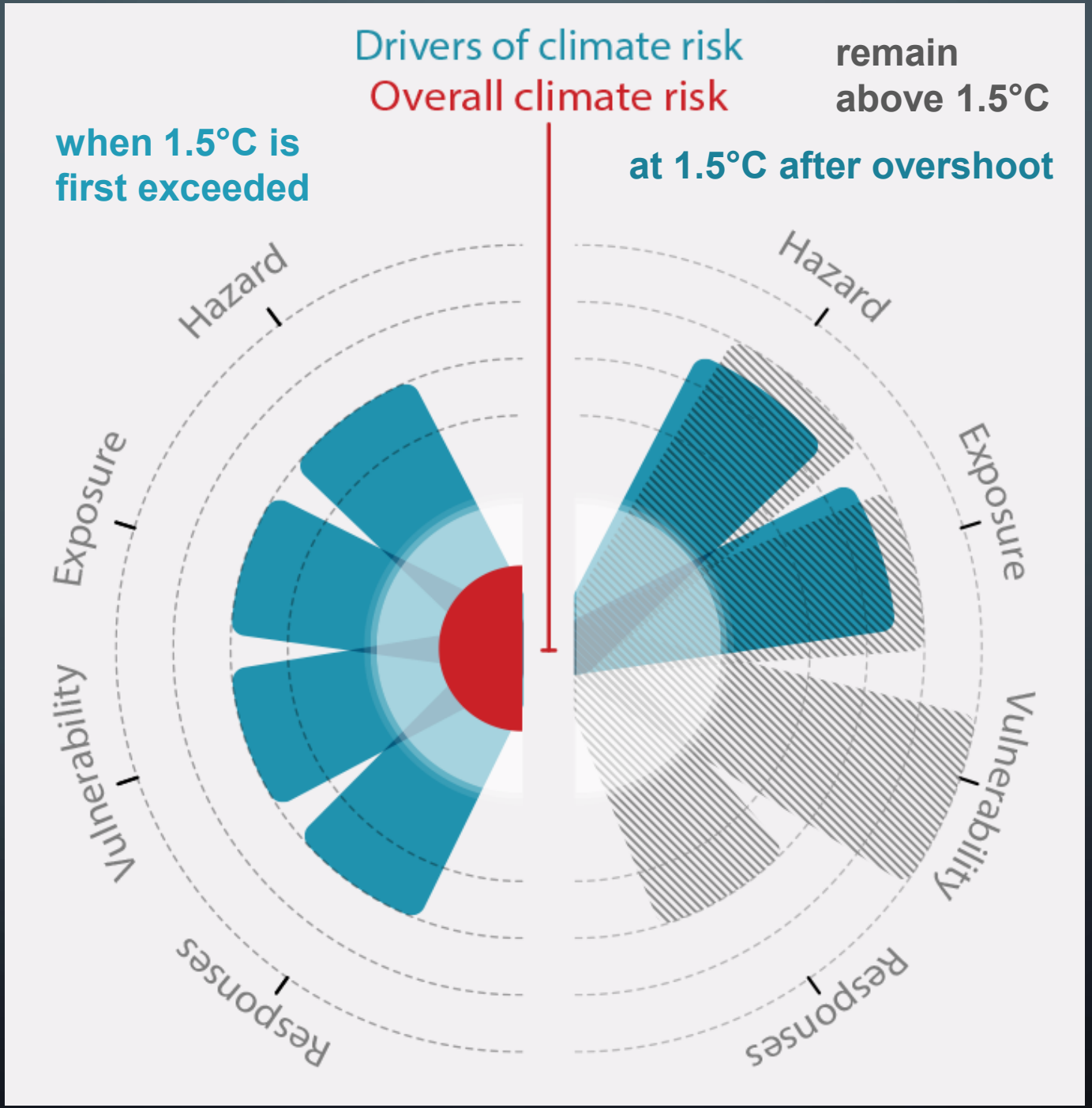

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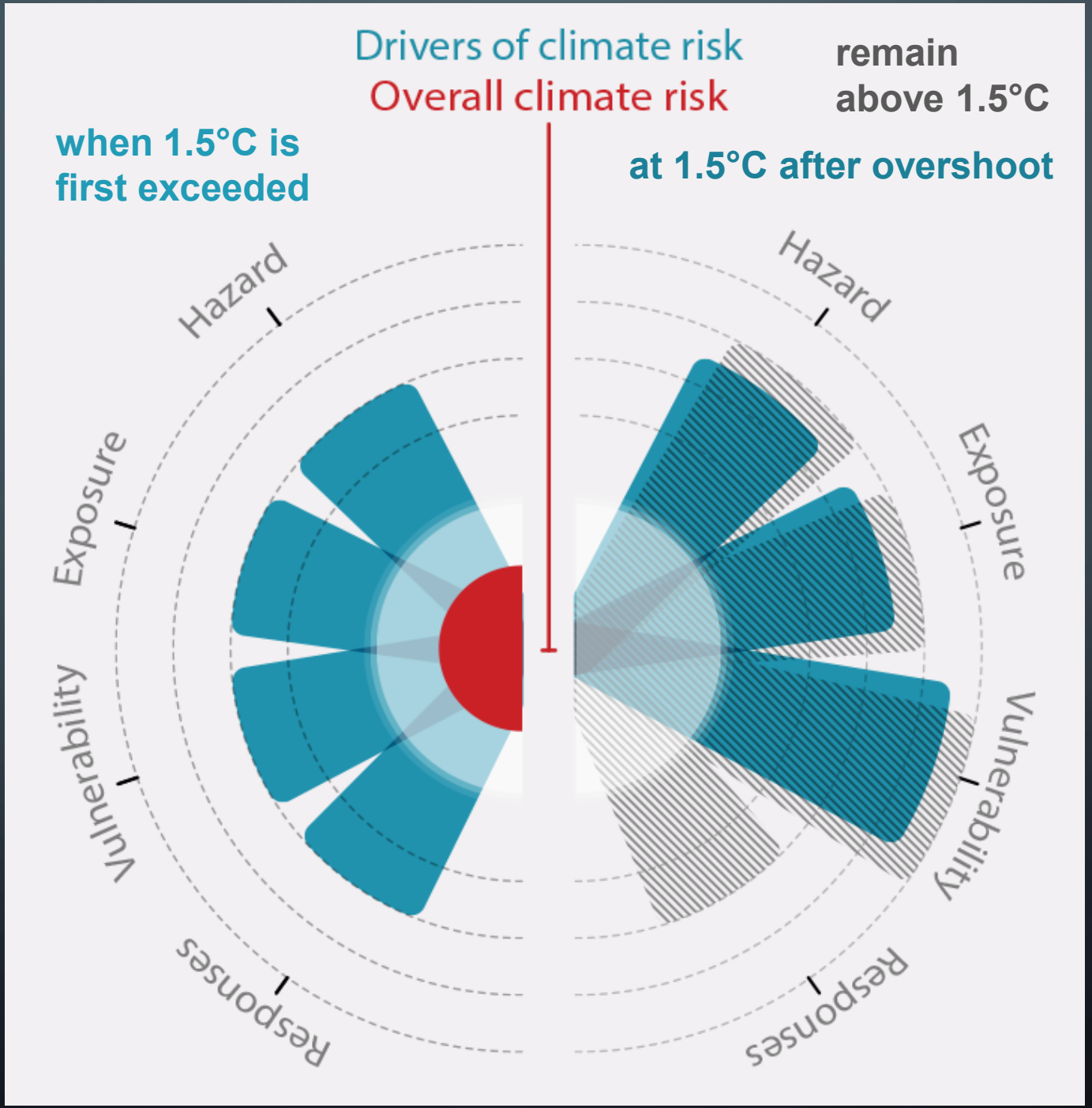

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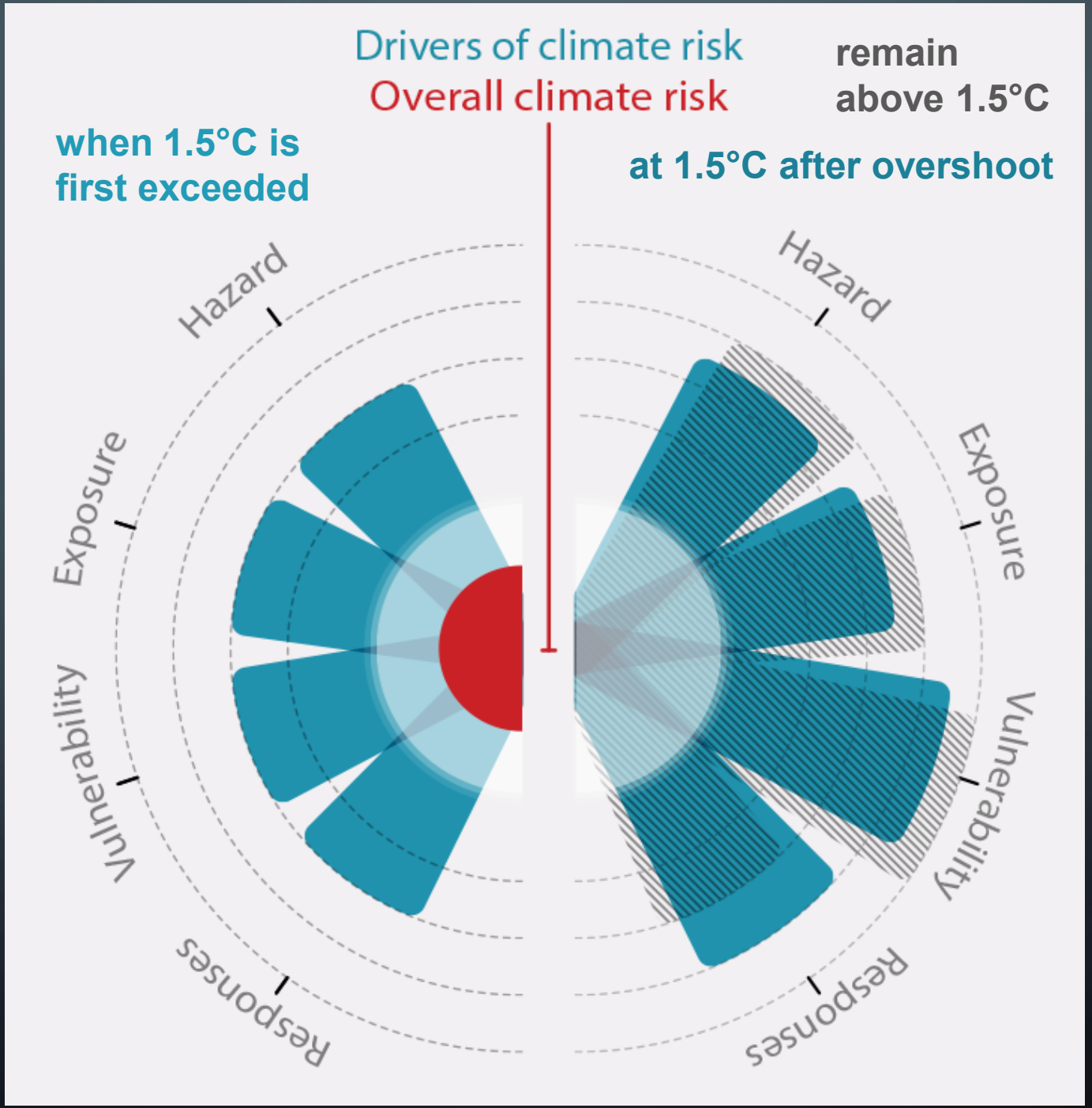

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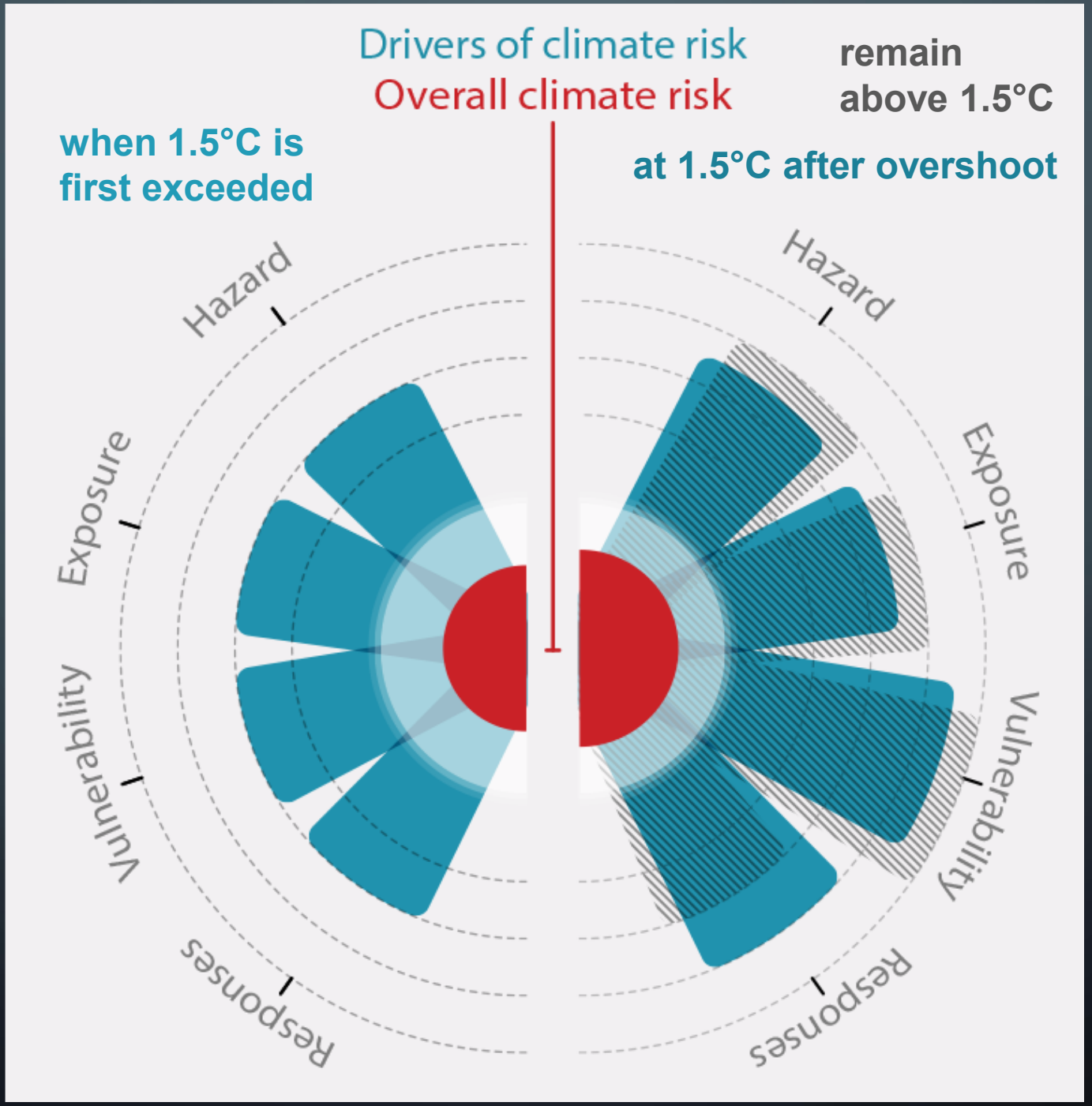
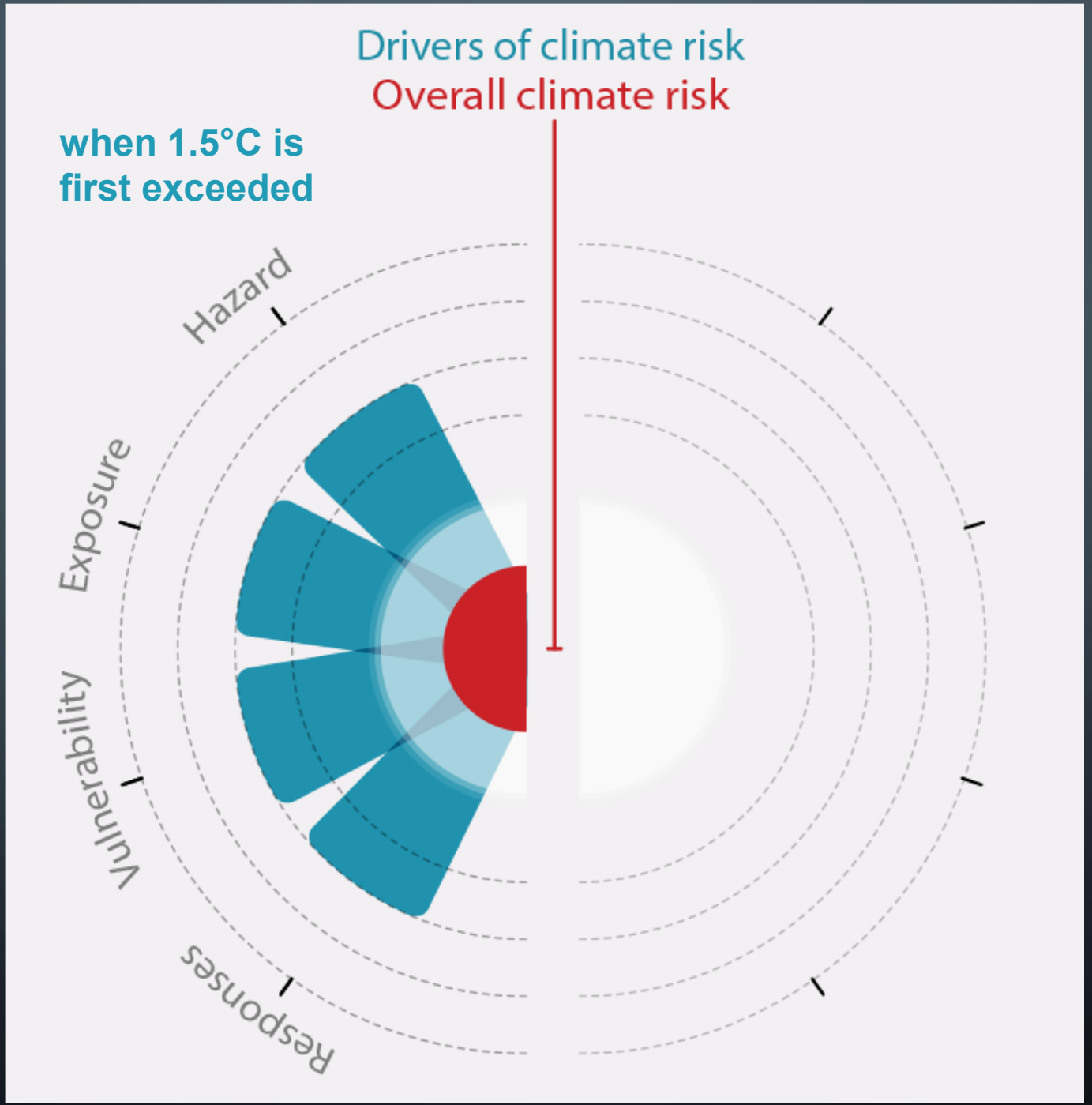


Risk could remain materially elevated:

- hazard and exposure do not fully reverse due to land-cover and land-use changes
- higher vulnerability due to poverty, intergenerational malnutrition, erosion of institutional capacity
- on-going pressure from land-based CDR

Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

Example: Heat wave mortality



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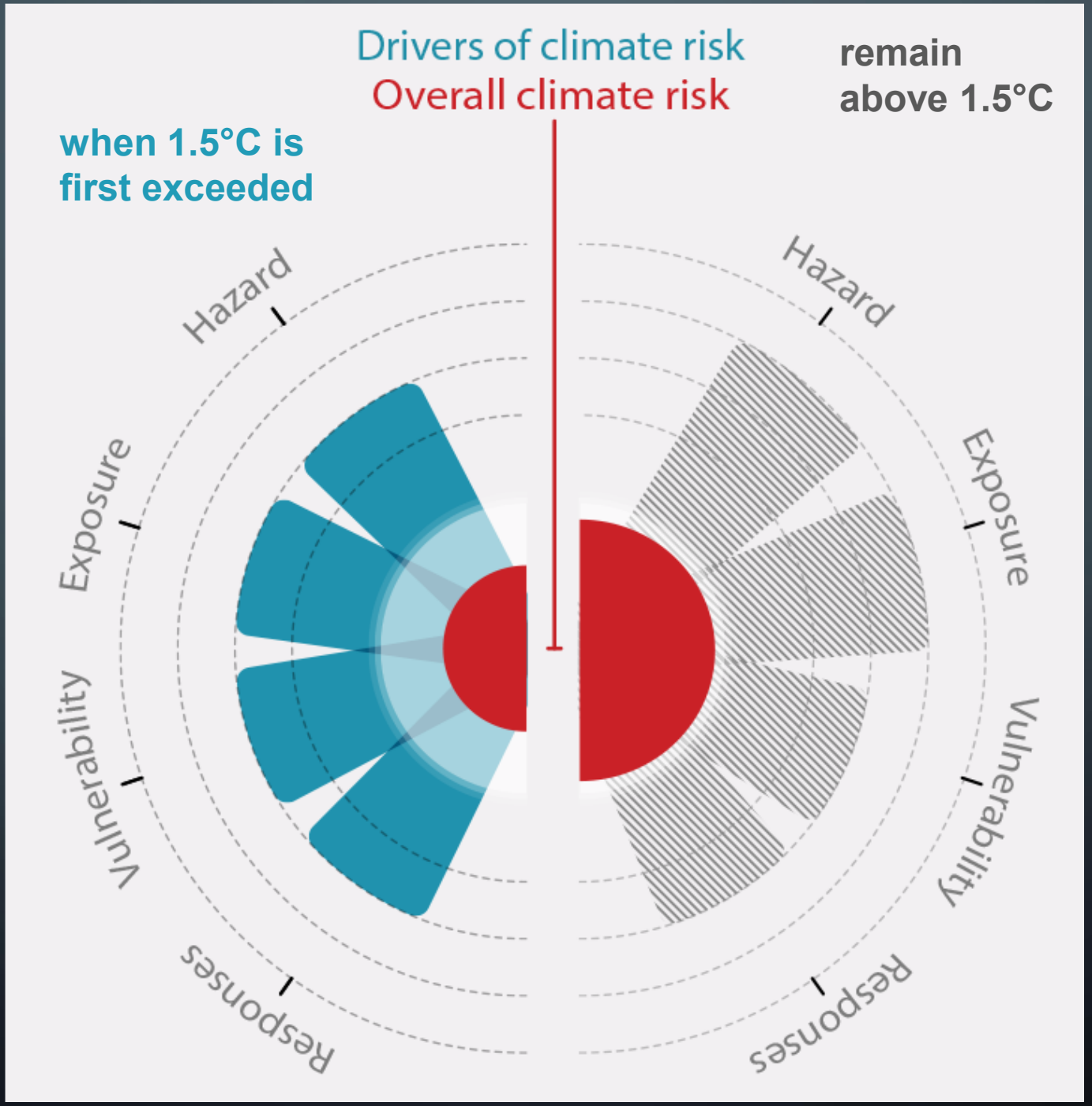

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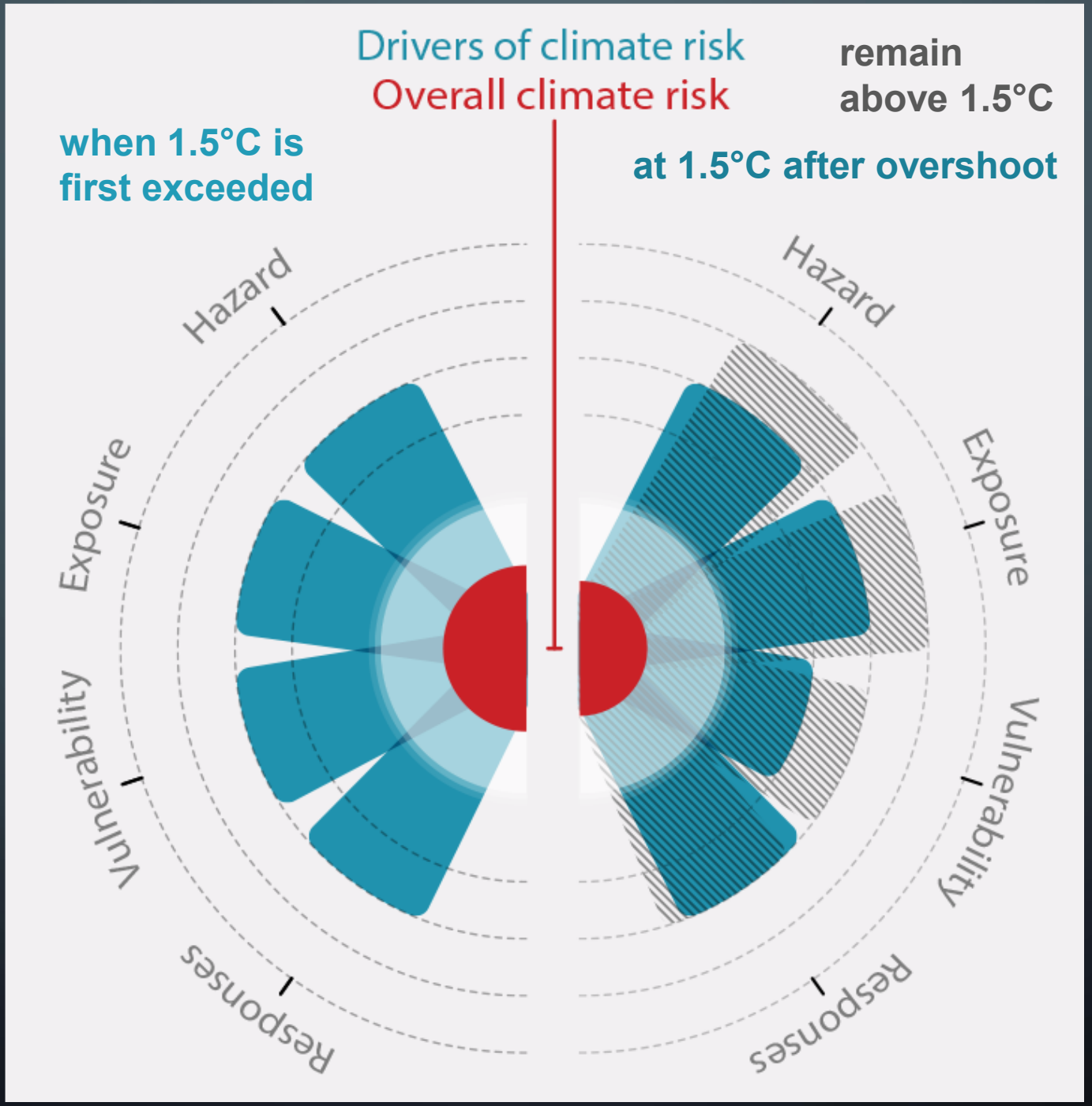


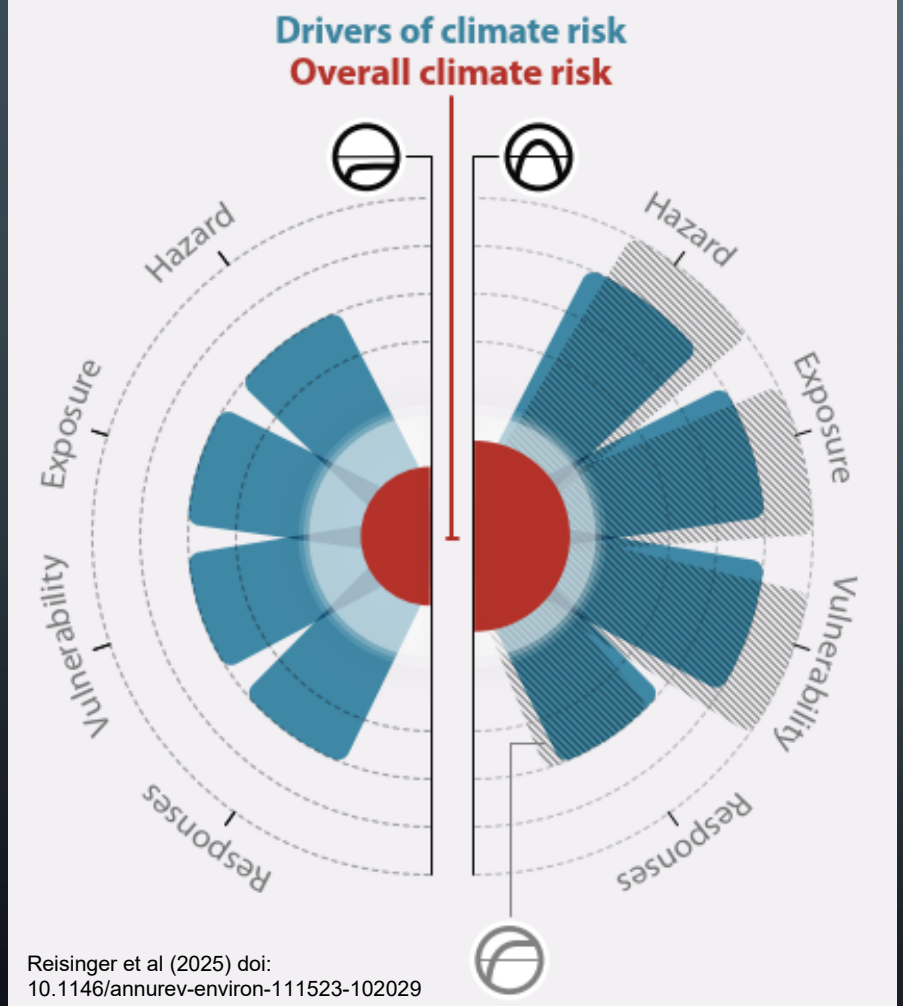
Risk could decline below pre-overshoot levels

if the overshoot period results in effective adaptation measures to reduce vulnerability

Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

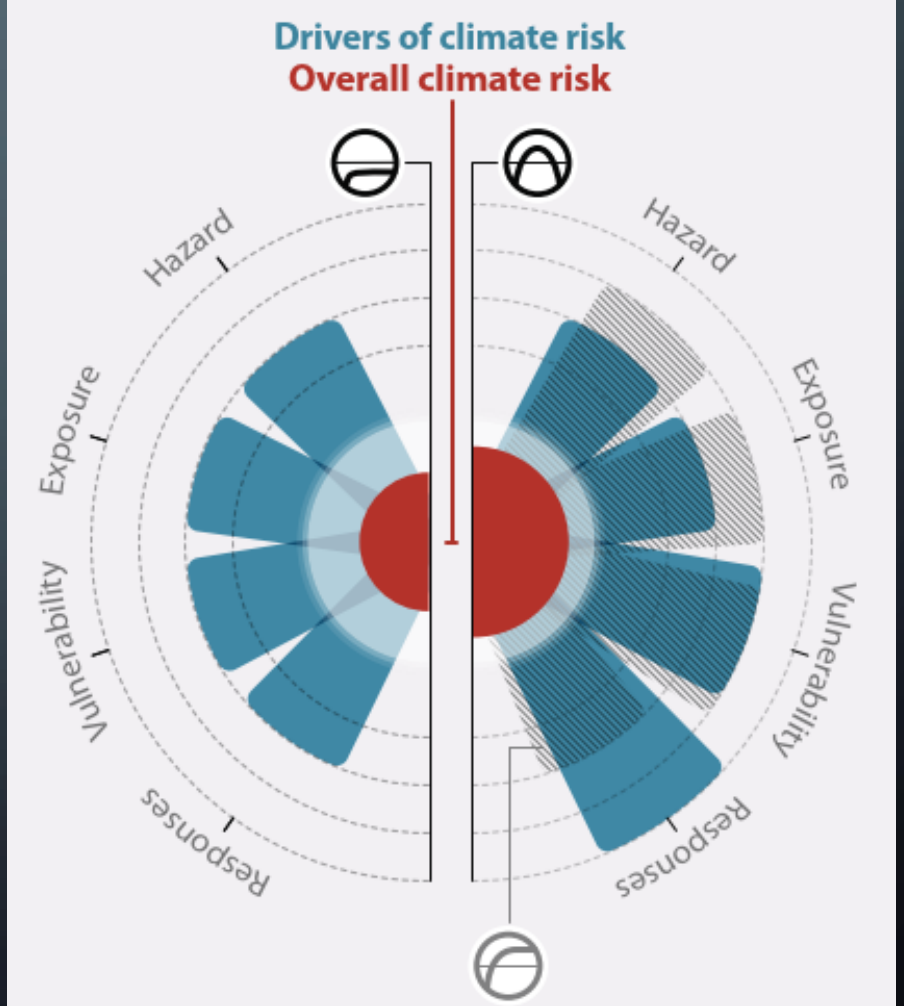
EVOLUTION OF RISK DEPENDS ON CONTEXT

Example b: **Coastal erosion and inundation from sea level rise** (escalating climate risk in overshoot due to increasingly severe hazard, exposure and vulnerability)



Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

Example c: **Ecosystem disturbances intensified by land demand for mitigation** (increased climate risk in overshoot due to mitigation compounding vulnerability)



A world that returns to 1.5°C after overshoot will be more vulnerable and more damaged than if we had never exceed 1.5°C …

… but a return to 1.5°C would reduce many risks and avoid further losses compared to a world that remains above 1.5°C permanently

ENDURING ADAPTATION NEEDS

- existing adaptation gaps
- existing adaptation finance gaps
- competition for climate finance and policy attention
- perception risk that adaptation is no longer critical if there is an in-principle commitment to reverse warming
- increasing risks in near-term; potential under-investment if adaptation plans assume successful reversal
- high potential for inequitable distribution of benefits and widening gaps under reversal of warming

CHALLENGES AND CHOICES TO REVERSE WARMING

- explicit global consensus about return to 1.5°C ?
  (Paris Article 4.1 can only get us there if overshoot is very limited)
- global burden-sharing on steroids
- beyond “net-zero”: (front-runner) countries/corporates need net-negative targets and credible pathways for delivery by 2050
- beyond “polluter-pays”: challenges to Emissions Trading Schemes
- redefining role of governments and societal consensus in driving net-negative emissions; domestic and sectoral burden sharing

What will it take to “Keep 1.5°C Alive” ?

1.5°C has enduring relevance beyond hindsight and grief

Navigating a return back to 1.5°C (“overshoot”):

1. **limit peak warming as close as possible to 1.5°C**
2. **prepare to reduce warming after the peak**

A clear value proposition for a return to 1.5°C

Pathways, targets and policy tools for sustained net-negative emissions

Limits to feasible temperature decline ⟷ overconfidence in overshoot

Embed adaptation in overall strategy

What will it take to “Keep 1.5°C Alive” ?

1.5°C h

“ **Researchers and policymakers will need to find opportunities to begin regular conversations about overshoot**

to refine knowledge needs, research gaps, and windows of opportunity for a post-peak return to 1.5°C. “

Reisinger et al (2025) doi: 10.1146/annurev-environ-111523-102029

Lim ershoot

Embed adaptation

Thank you

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Start the conversation at the upcoming overshoot conference:

https://overshootconference.org/