State of Climate Change
Planetary Boundaries

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April: Heat waves in India, Bangladesh, Thailand and Philippines

April - May: Record flooding in Brasil - up to half of the annual predicted rain fell in just 10 days

April : UAE flooding

March - May : Kenya flooding

May: Cyclone Remal – Bangladesh

Fires – April through September

All these events have become more likely because of climate change.

Impacts are current reality.
Not a problem of the future. They come thicker and faster than anticpated.

Climate Emergency in a nutshell

1. We are extremely close to our global temperature target of 1.5/2.0°C for 2100.

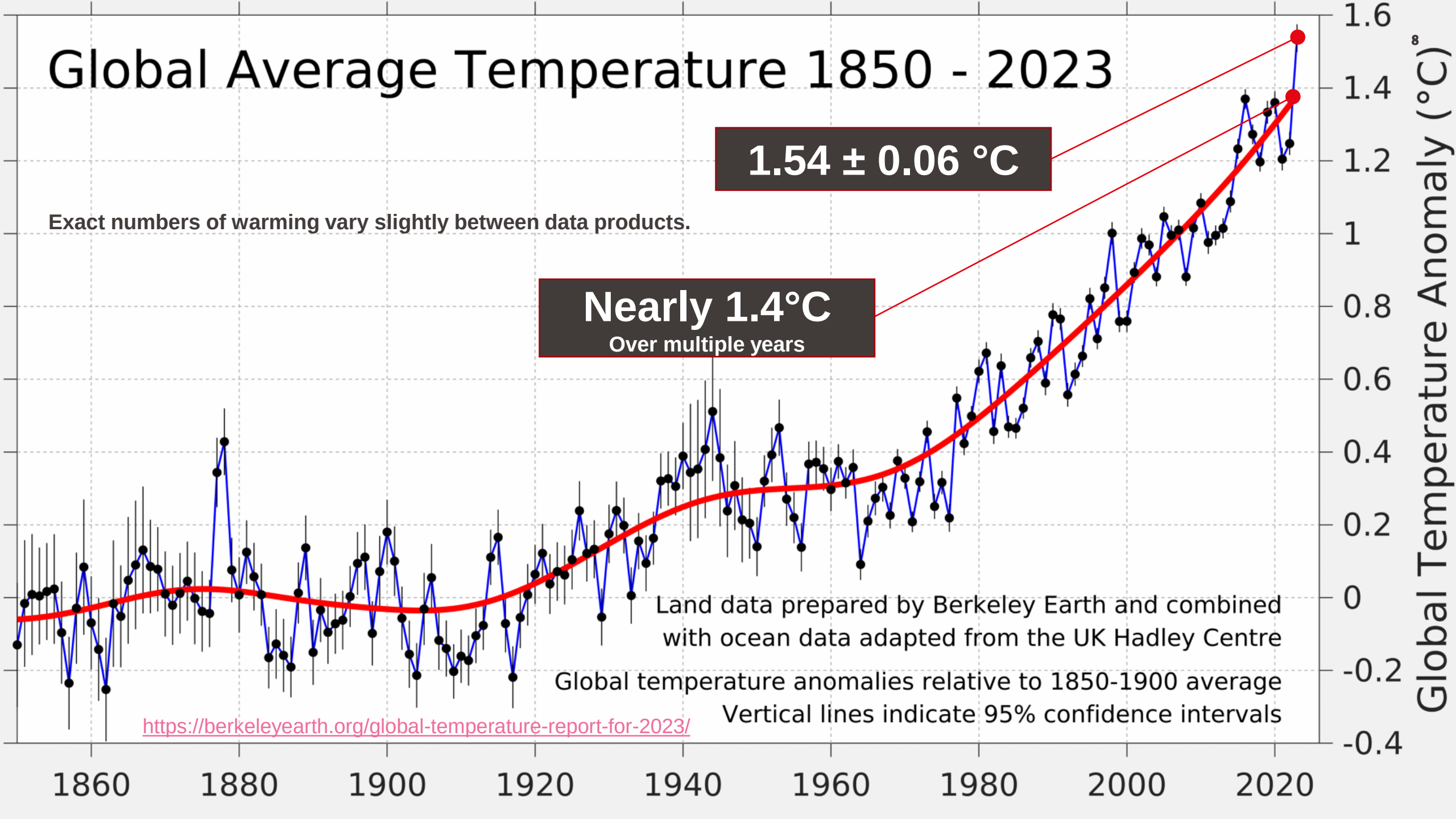
2. Drastic emission reductions are needed now and net-zero needs to be achieved by 2050.

3. Humanity is faced with a technological, political and behavioral challenge never encountered before.

We're late.

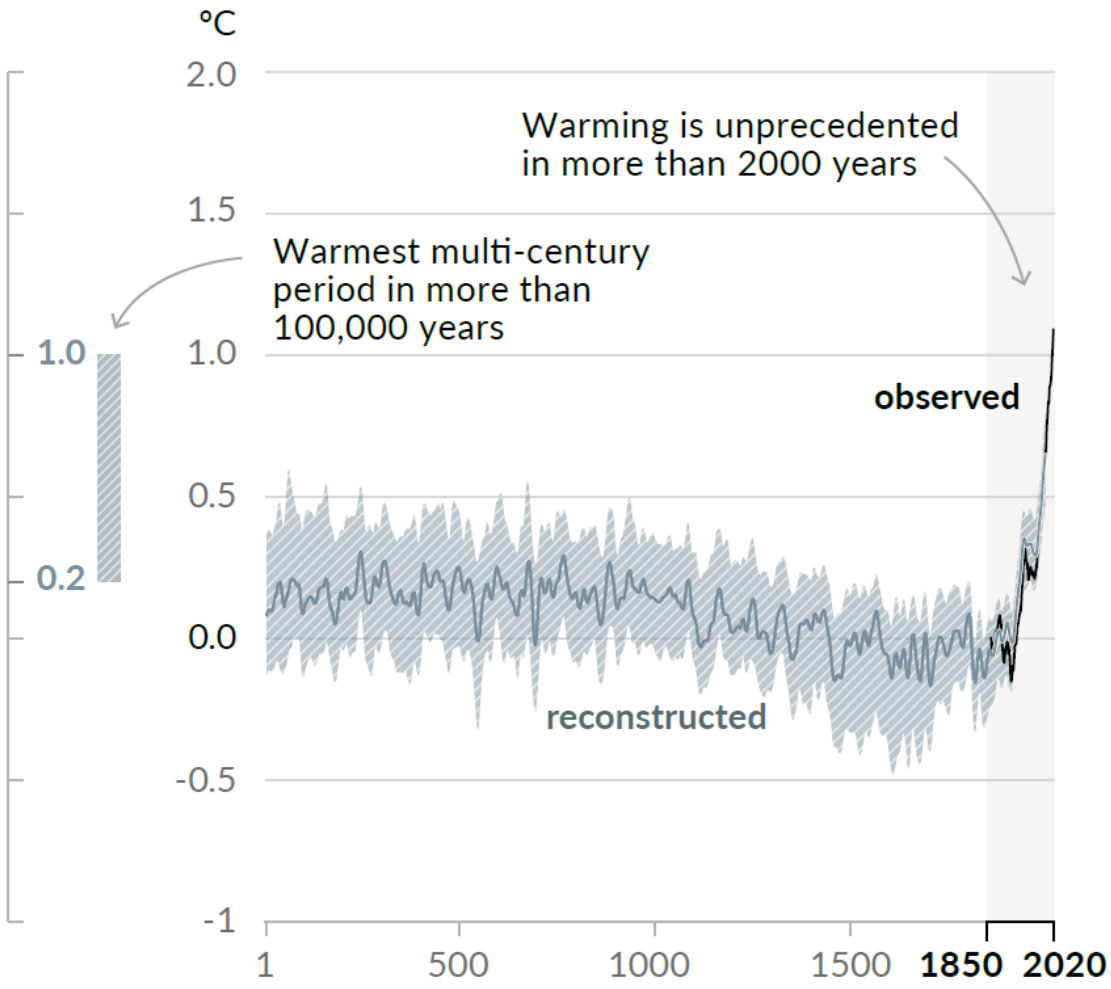
We need to hurry up.

We need to run faster than ever before.

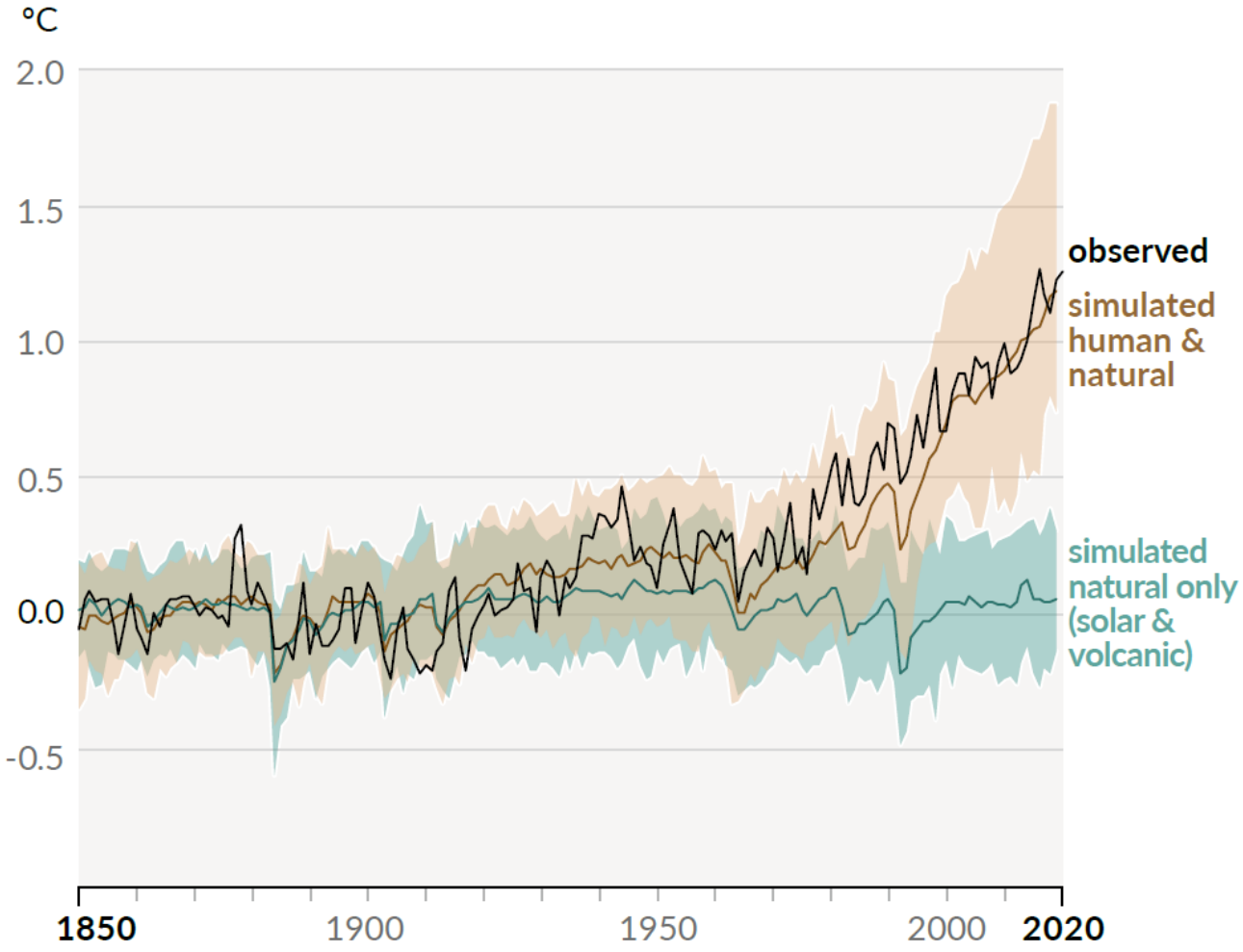

Global Average Temperature 1850 - 2023
1.54 ± 0.06 °C
Exact numbers of warming vary slightly between data products.
Nearly 1.4°C
Over multiple years
Land data prepared by Berkeley Earth and combined
with ocean data adapted from the UK Hadley Centre
Global temperature anomalies relative to 1850-1900 average
Vertical lines indicate 95% confidence intervals
https://berkeleyearth.org/global-temperature-report-for-2023/
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Global Temperature Anomaly (°C)
1860
1880
1900
1920
1940
1960
1980
2000
2020

Global temperature change

a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and **observed** (1850-2020)

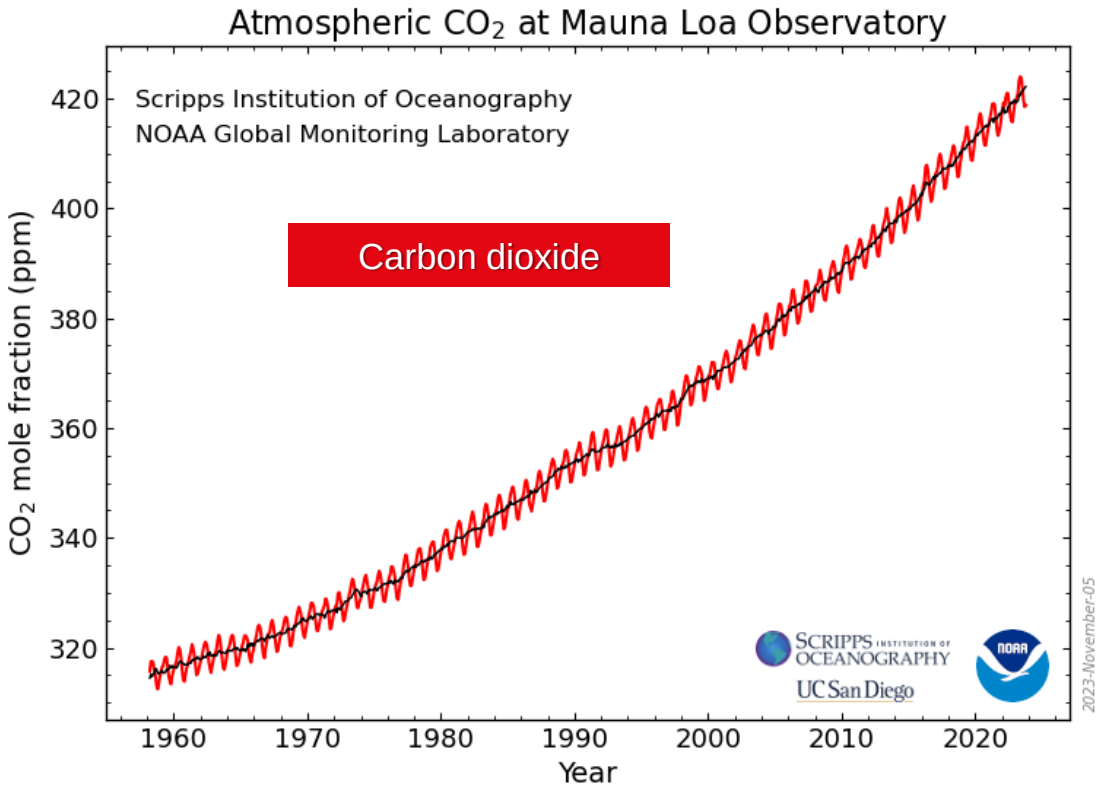


b) Change in global surface temperature (annual average) as **observed** and simulated using human & natural and only natural factors (both 1850-2020)



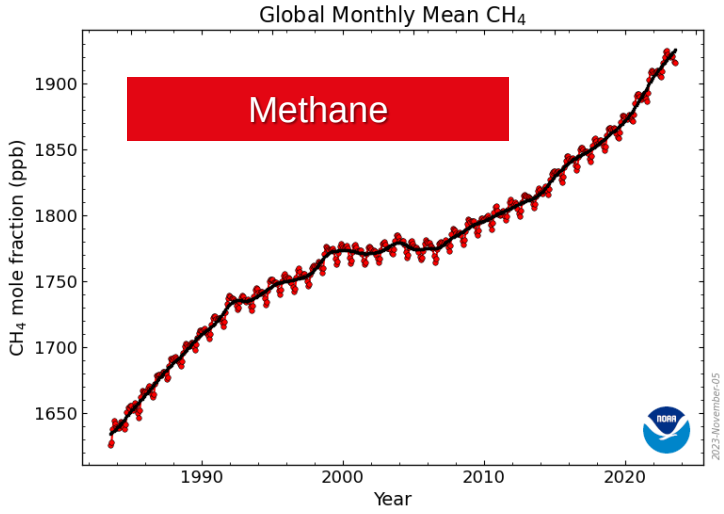
- IPCC, AR6, Summary for Policy Makers (SPM), Figure SPM1

Trends of greenhouse gases in the atmosphere



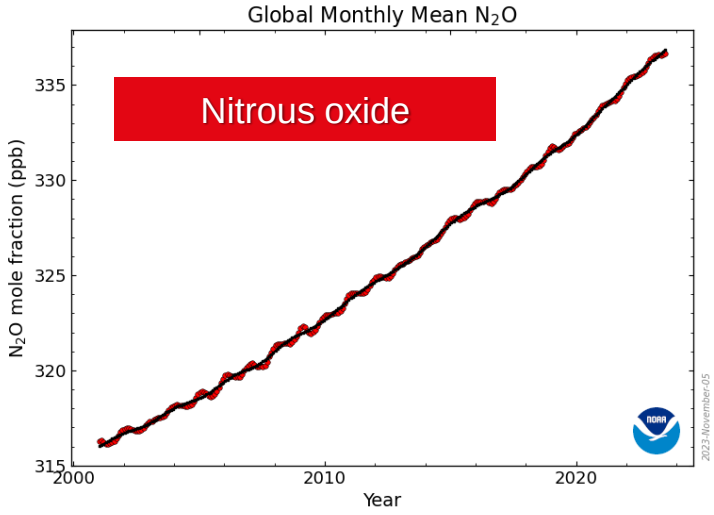
October 2023: 418.82 ppm
October 2022: 415.74 ppm
Last updated: Nov 05, 2023

Most important
Source: combustion
Lifetime: ~100 years



July 2023: 1915.25 ppb
July 2022: 1904.42 ppb
Last updated: Nov 05, 2023

2nd most important
Source: agriculture, energy, waste
Lifetime: ~12 years

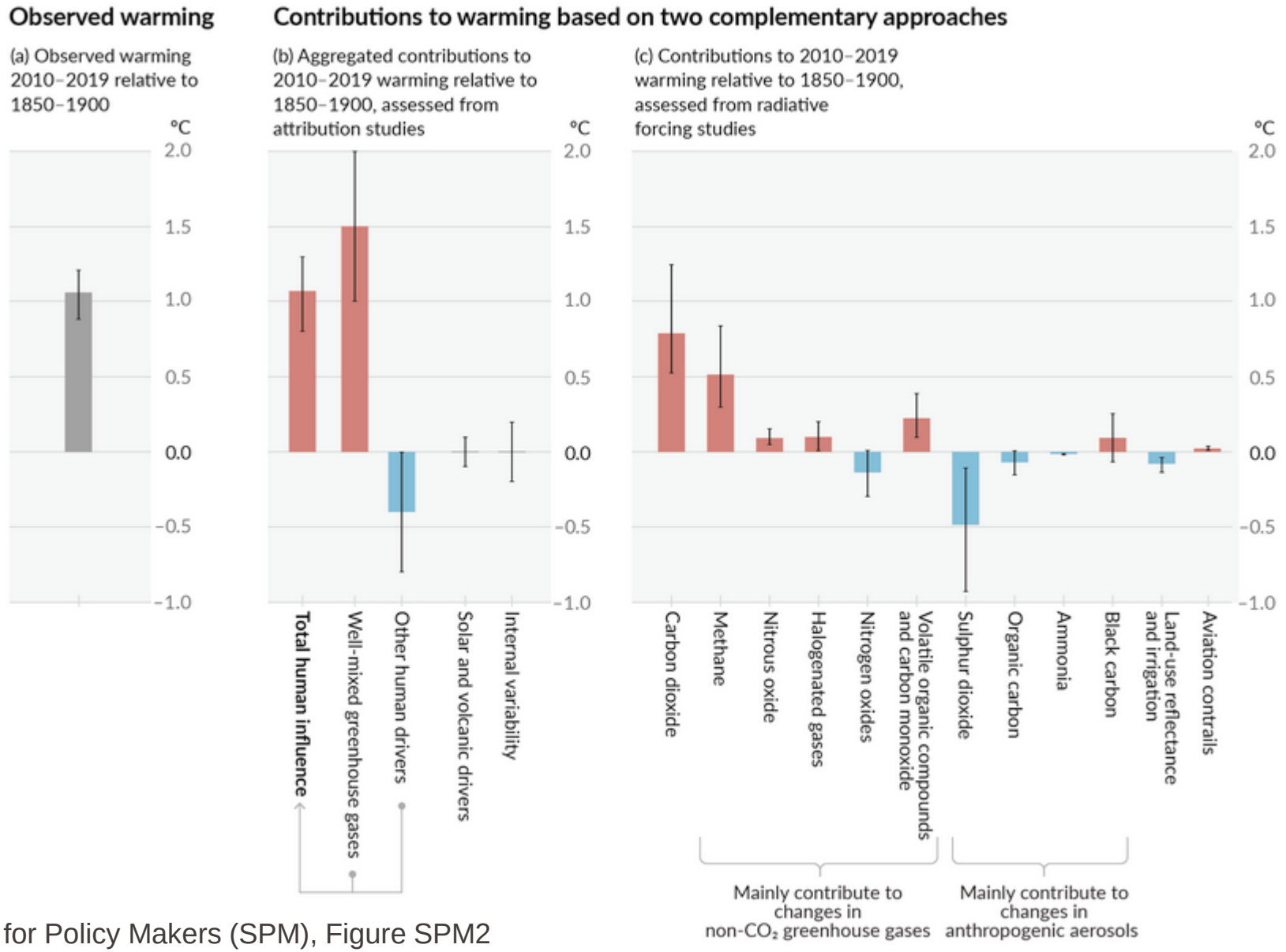


July 2023: 336.66 ppb
July 2022: 335.56 ppb
Last updated: Nov 05, 2023

important
Source: agriculture, waste
Lifetime: >100 years

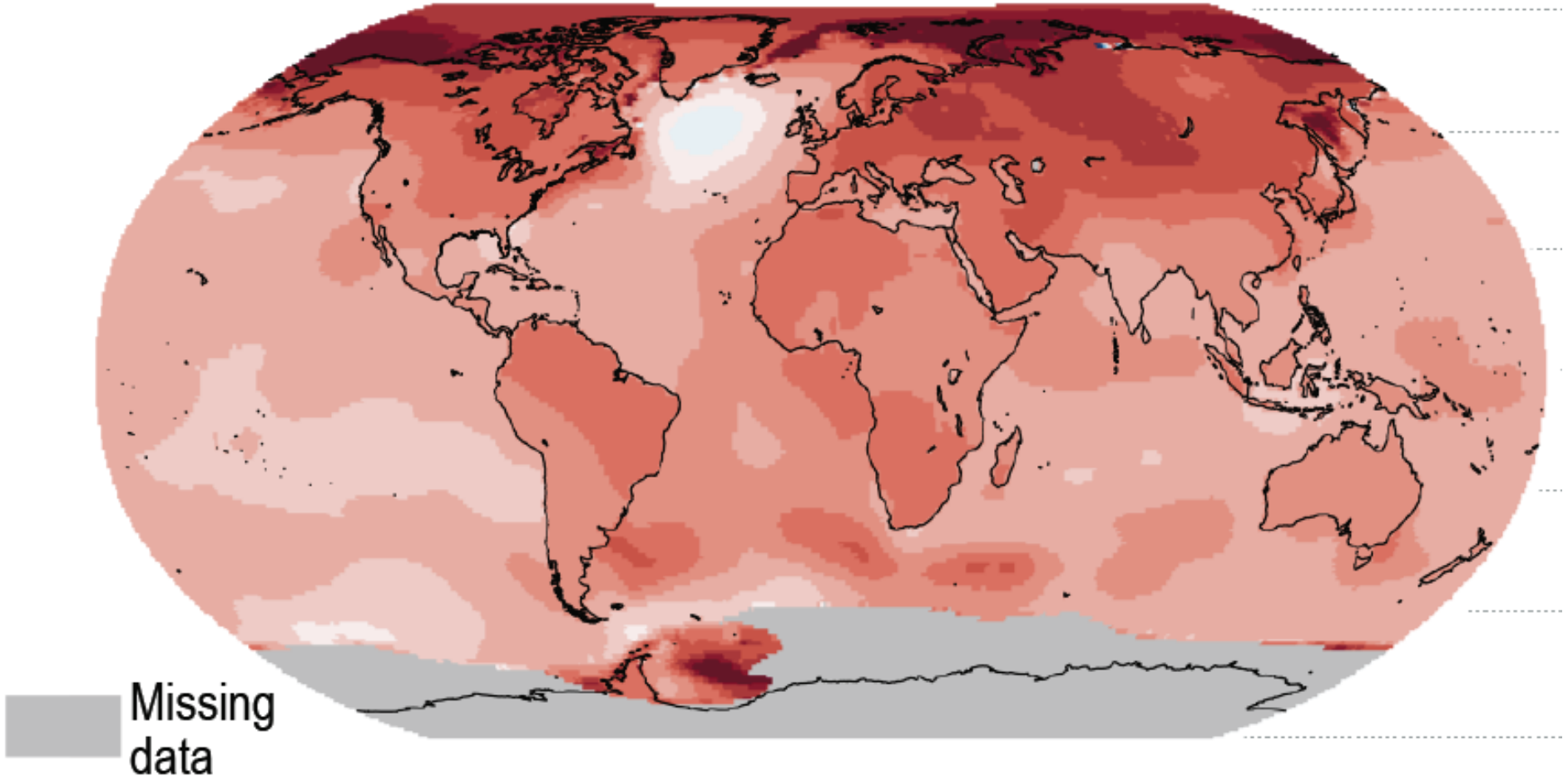
- https://gml.noaa.gov/ccgg/trends/

Importance of different emissions



- IPCC, AR6, Summary for Policy Makers (SPM), Figure SPM2

Regional warming differences



Paris Agreement 2015

*"The **Paris Agreement** central aim is to [...]*
keep global temperature rise [...] well below 2°C above pre-industrial levels
and to pursue efforts to limit the [...] increase [...] to 1.5 °C."

https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

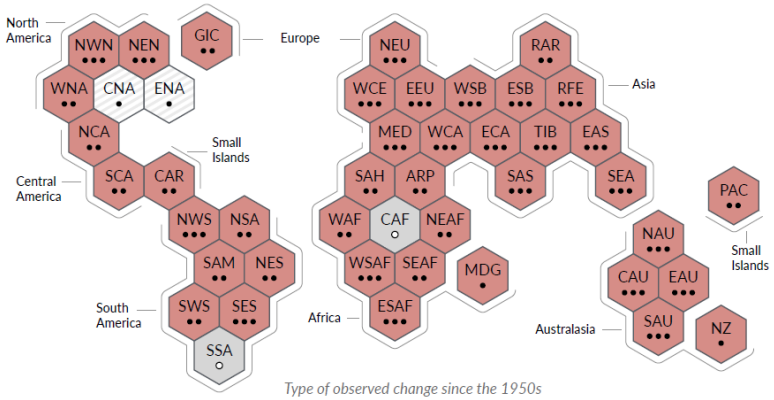
Why 1.5°C?
And what if we go beyond?

1.5°C versus warmer

- Limitation of global warming to 1.5°C compared to more than 2°C allows to avoid substantial additional changes in extremes and (irreversible) impacts:
  - Increase in **hot extremes** in most inhabited regions of the world
  - **Heavier precipitation accompanied by cyclones** in several regions
  - **Increased droughts** in some regions
  - **Irreversible impacts/tipping points**
    - sea level rise, extinction of animals, plants, corals…

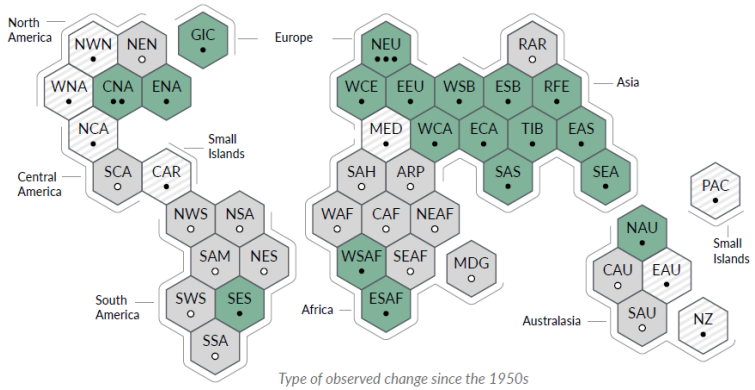
Hot extremes change today

a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



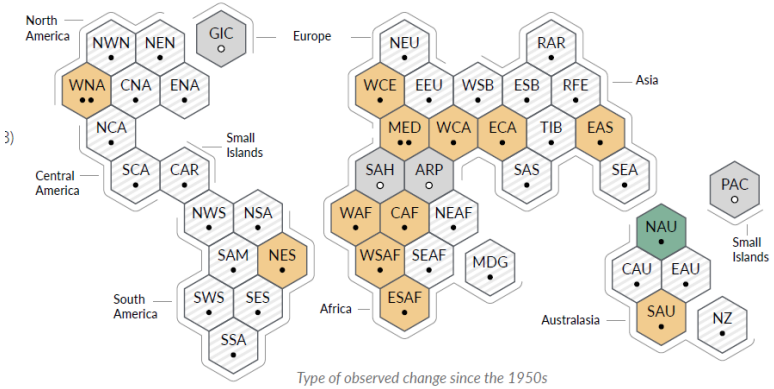
Heavy Precipitation change today

b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



Droughts change today

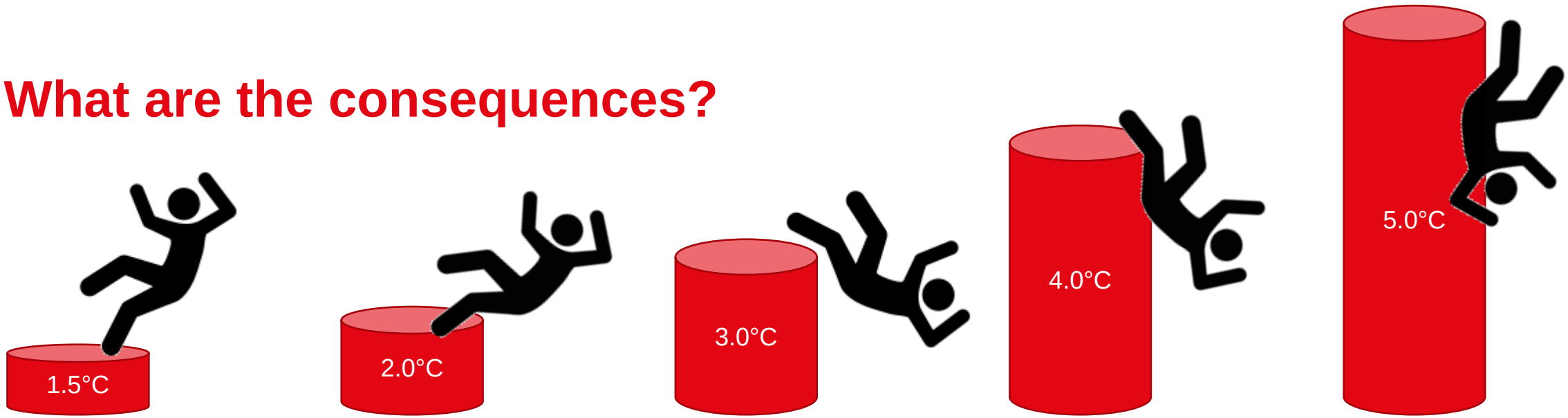
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



- UNFCC Emission Gap Report 2021; AR6, SR1.5

1.5°C versus warmer

What are the consequences?



Tipping points
Irreversible impacts

The Guardian, 2019

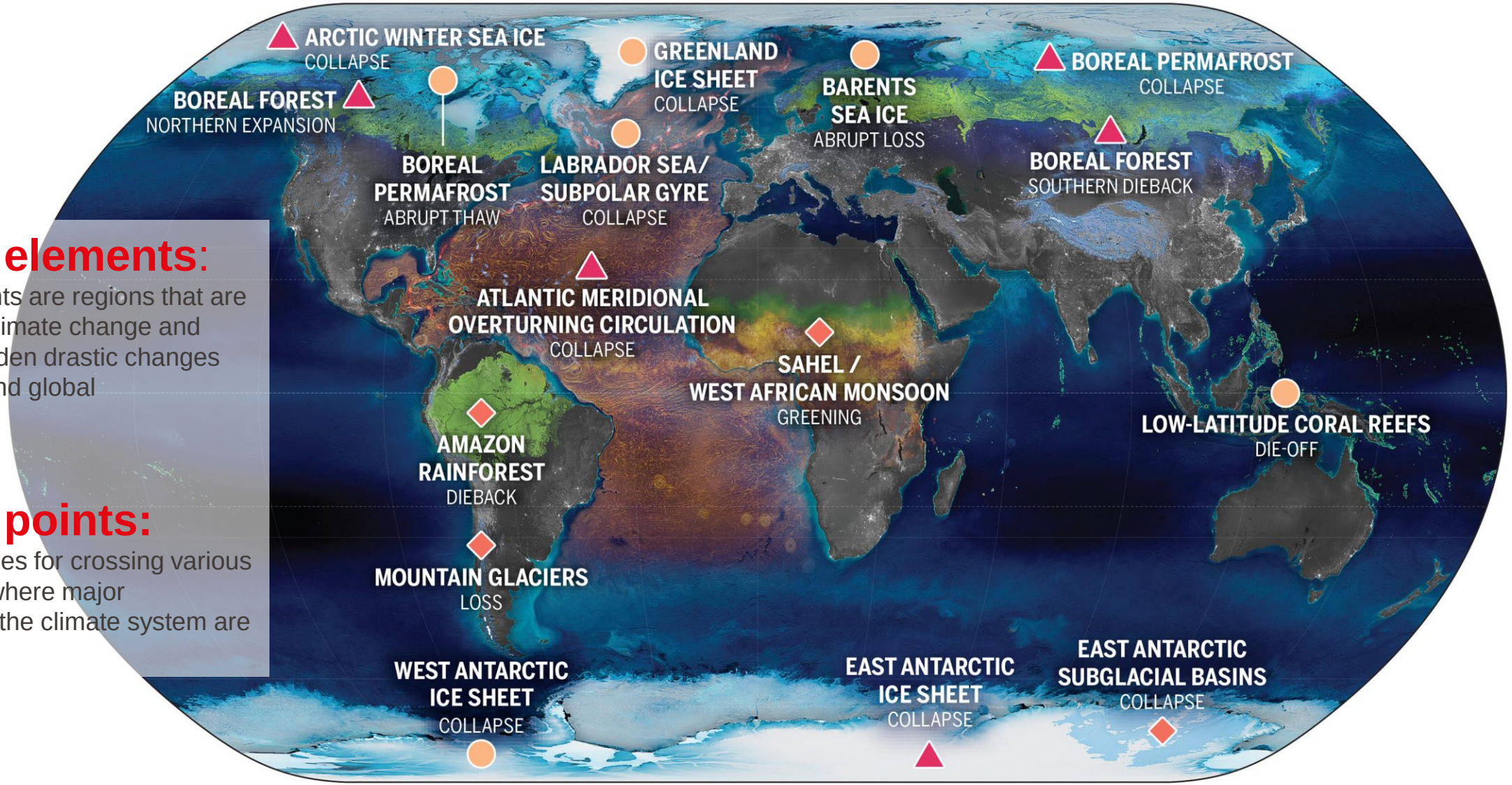
What is at stake?

Tipping elements:

Tipping elements are regions that are vulnerable to climate change and capable of sudden drastic changes with regional and global consequences.

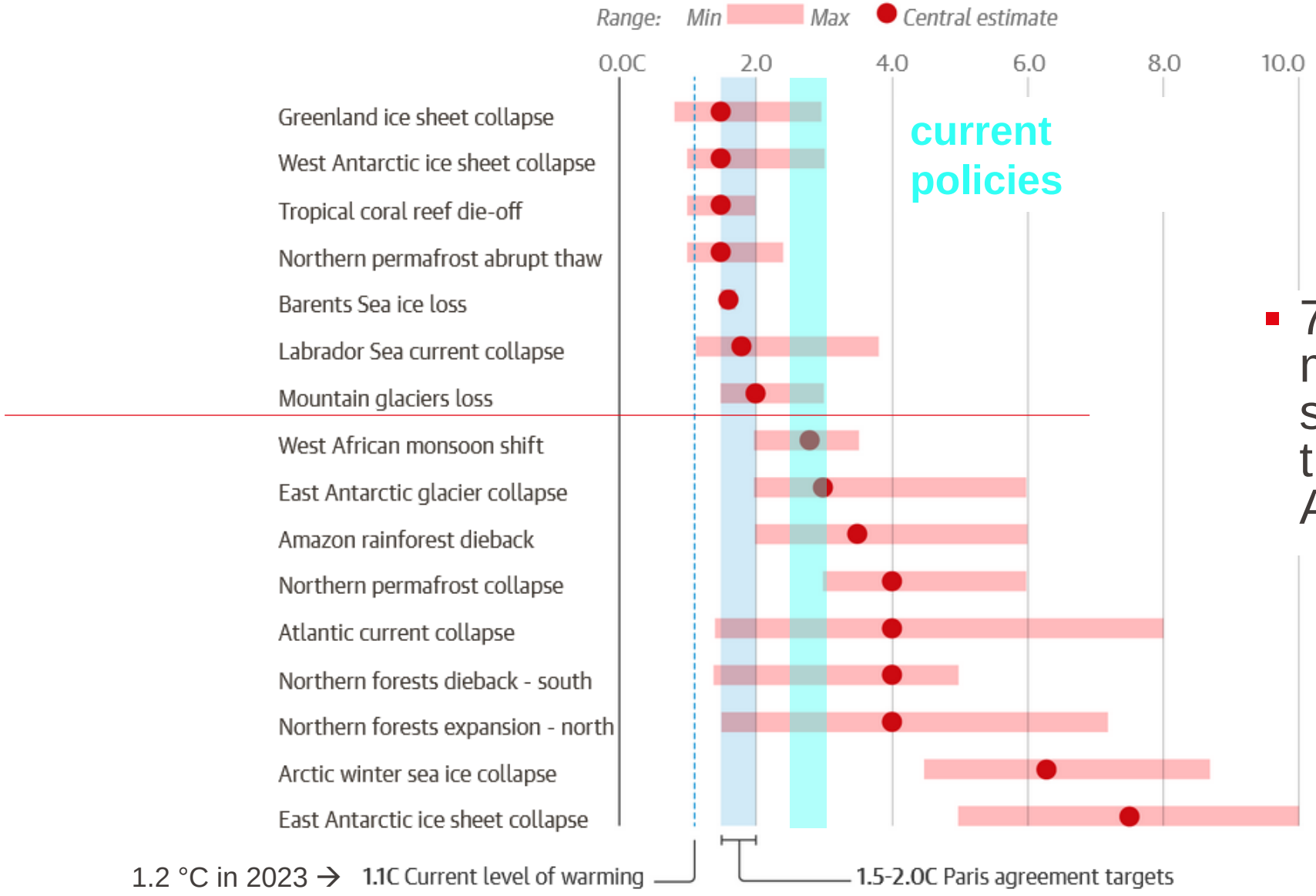
Tipping points:

Threshold ranges for crossing various tipping points where major subsystems of the climate system are destabilized.



Armstrong McKay et al., 2022, Science

What can the Paris Agreement prevent?

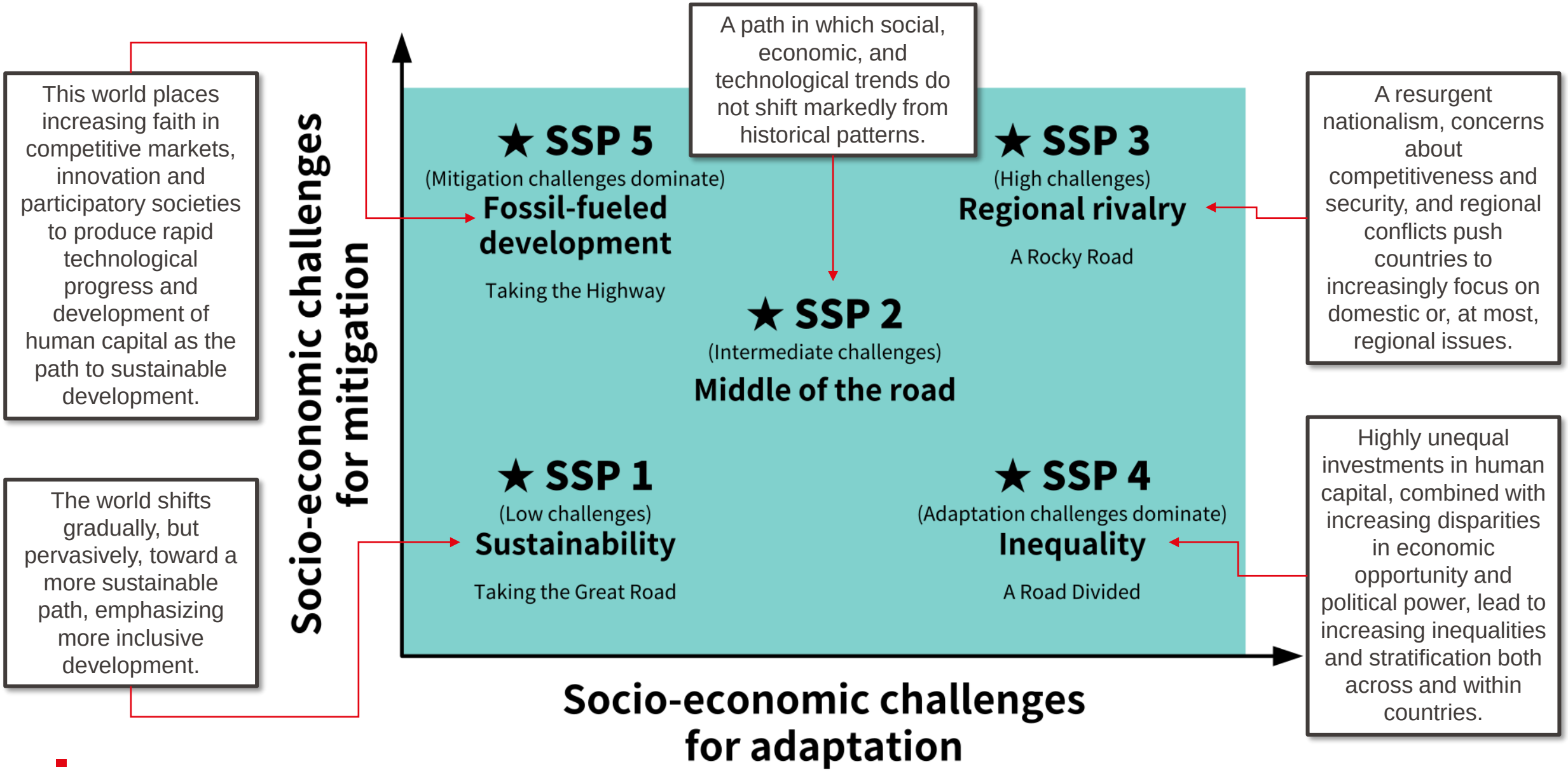


Guardian graphic. Source: Armstrong McKay et al, Science, 2022. Note: Current global heating temperature rise 1.1C Paris agreement targets 1.5-2.0C

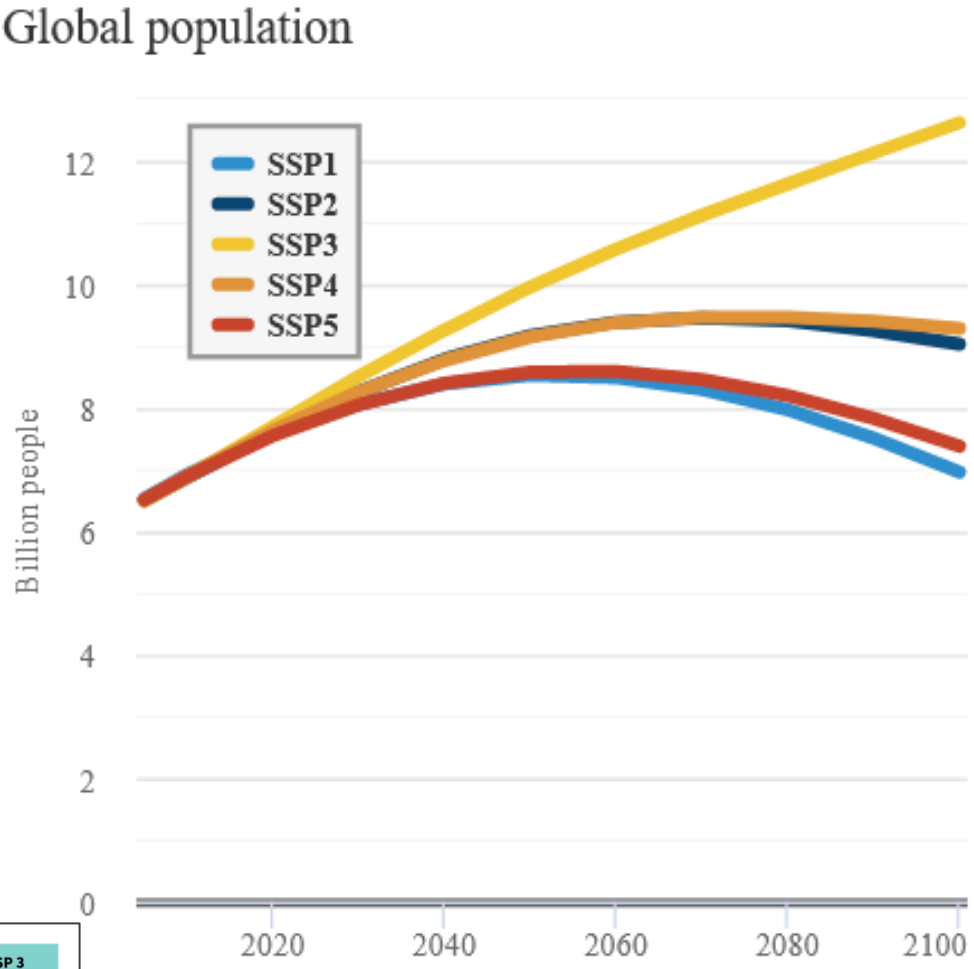
- 7 tipping points might be surpassed within the Paris Agreement range

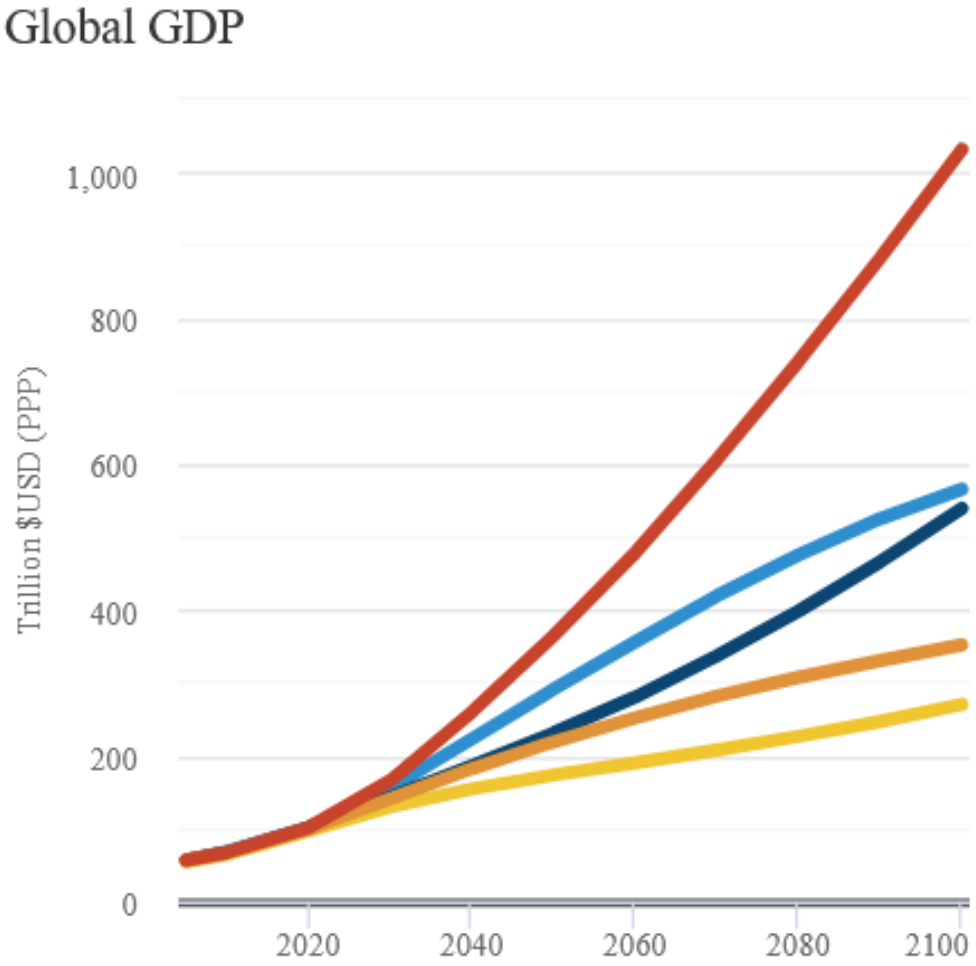
Pathways

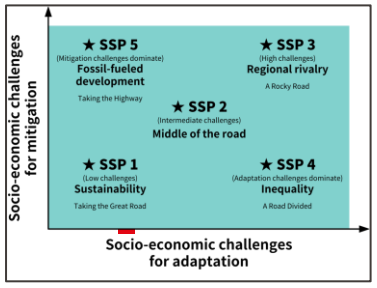
Shared Socio-economic Pathways (SSPs)



SSPs narratives



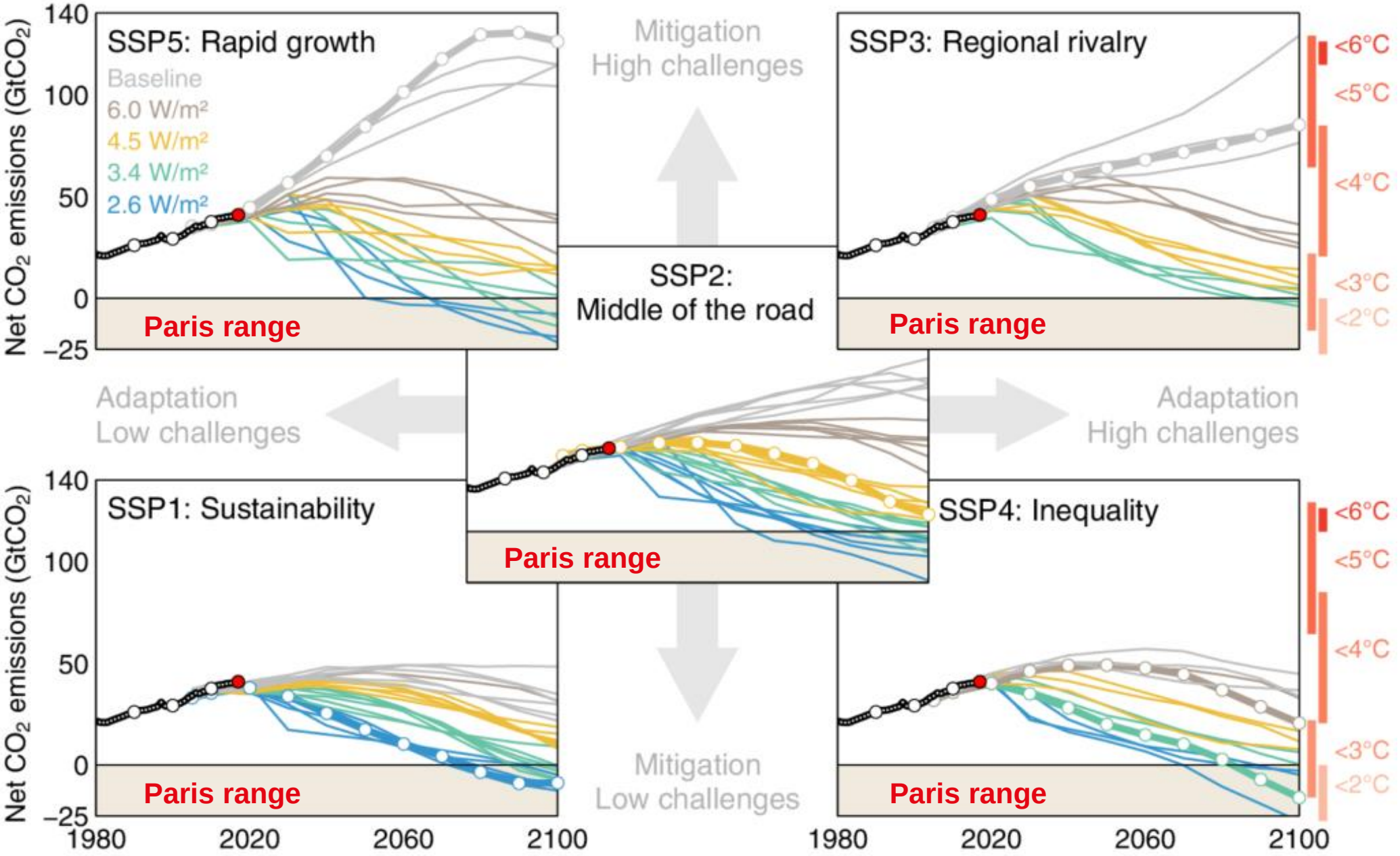


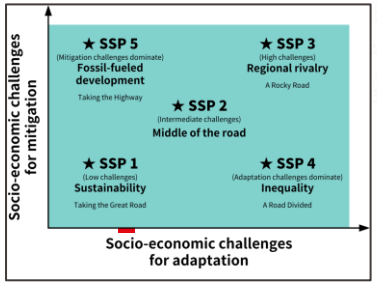


Grey: no climate policy

Colors: with climate policy

Top scenario





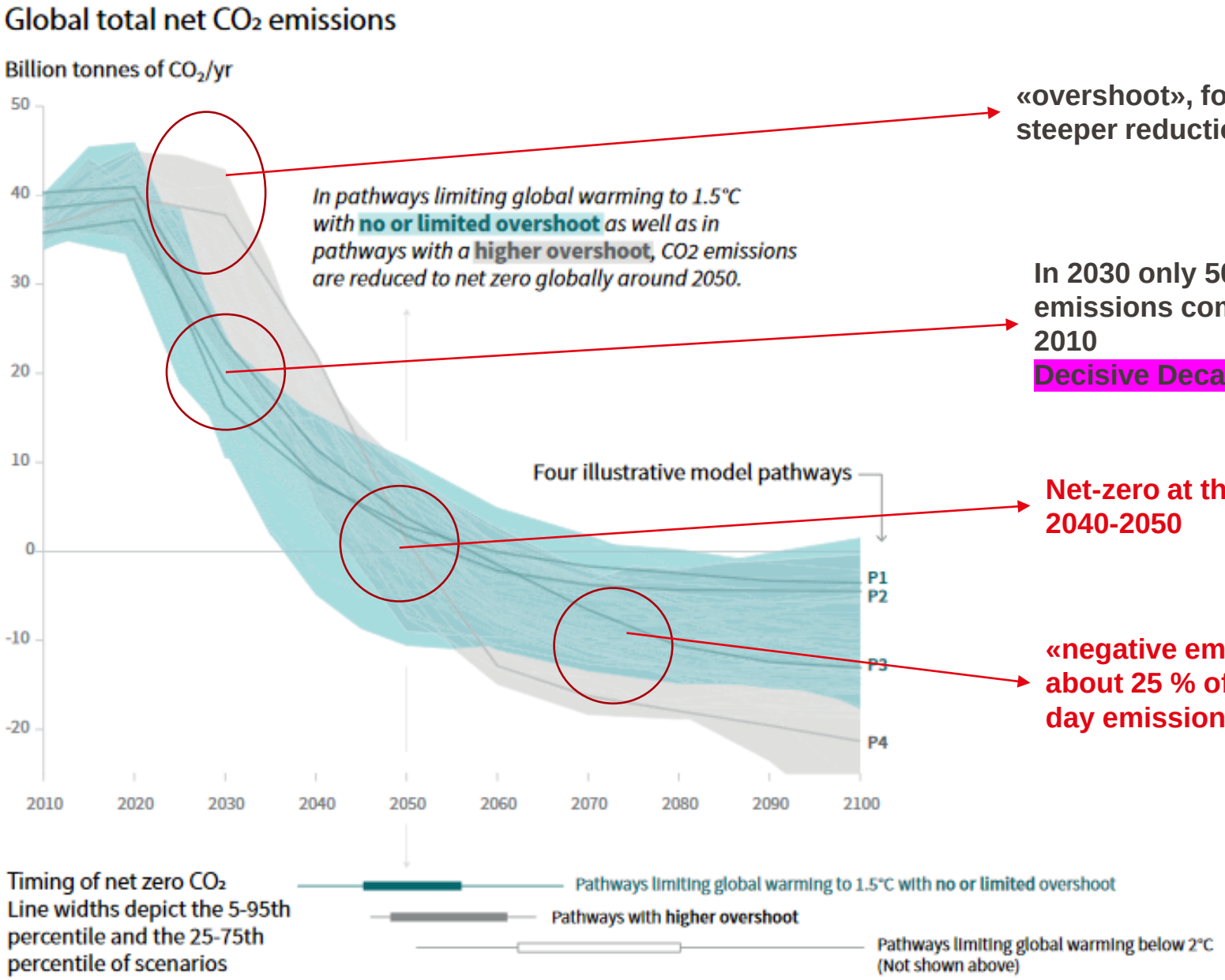
Climate Emergency in a nutshell

1. We are extremely close to our global temperature target of 1.5/2.0°C for 2100.

2. Drastic emission reductions are needed now and net-zero needs to be achieved by 2050.

3. Humanity is faced with a technological, political and behavioral challenge never encountered before.

Reducing emissions



«overshoot», followed by steeper reduction

In 2030 only 50 % of emissions compared to 2010
Decisive Decade

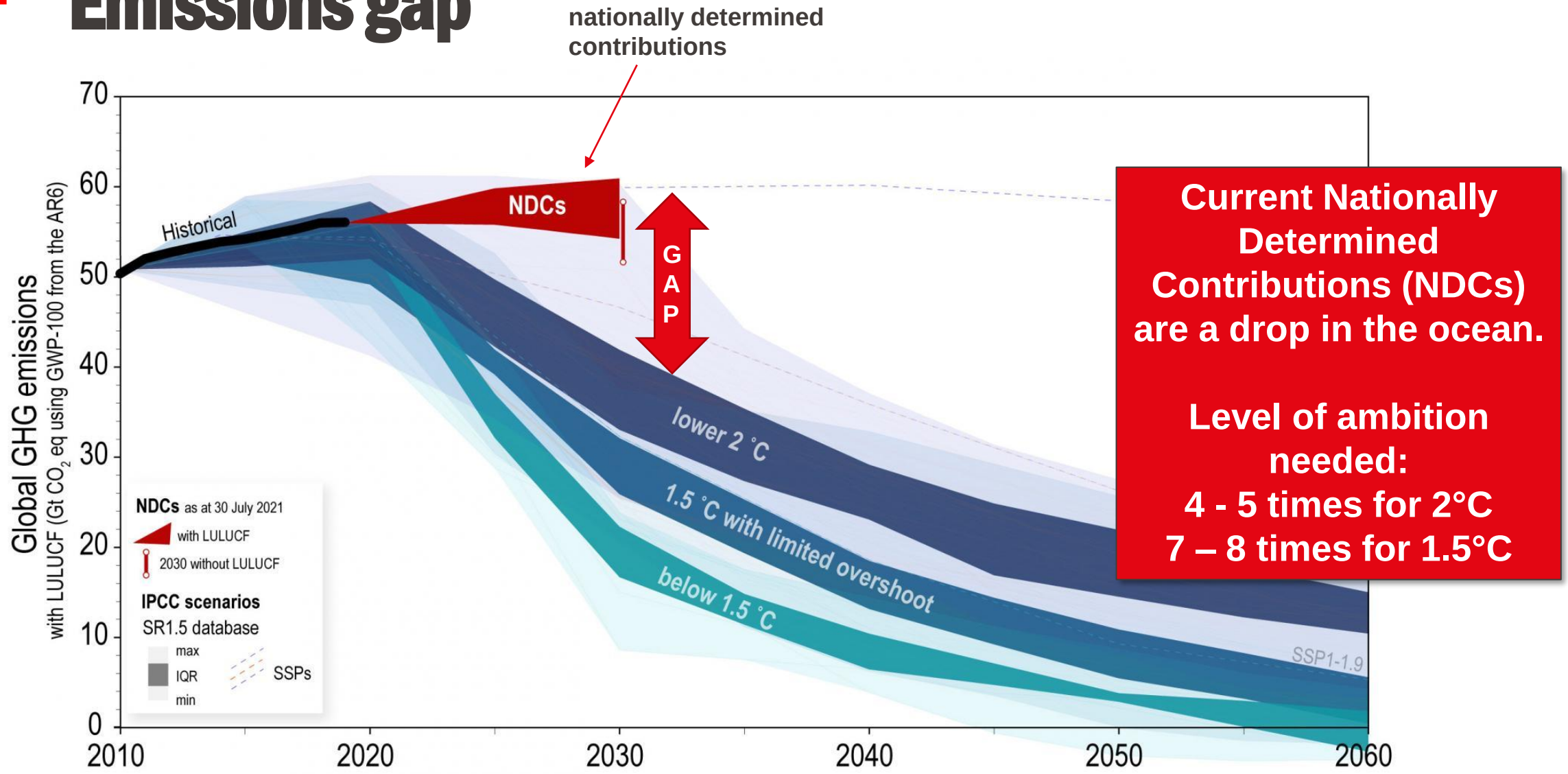
Net-zero at the latest in 2040-2050

«negative emissions» about 25 % of present-day emissions!

Reducing methane now vigorously while keeping to reduce CO_2 can help tackle the challenge.

IPCC, SP1.5

Emissions gap



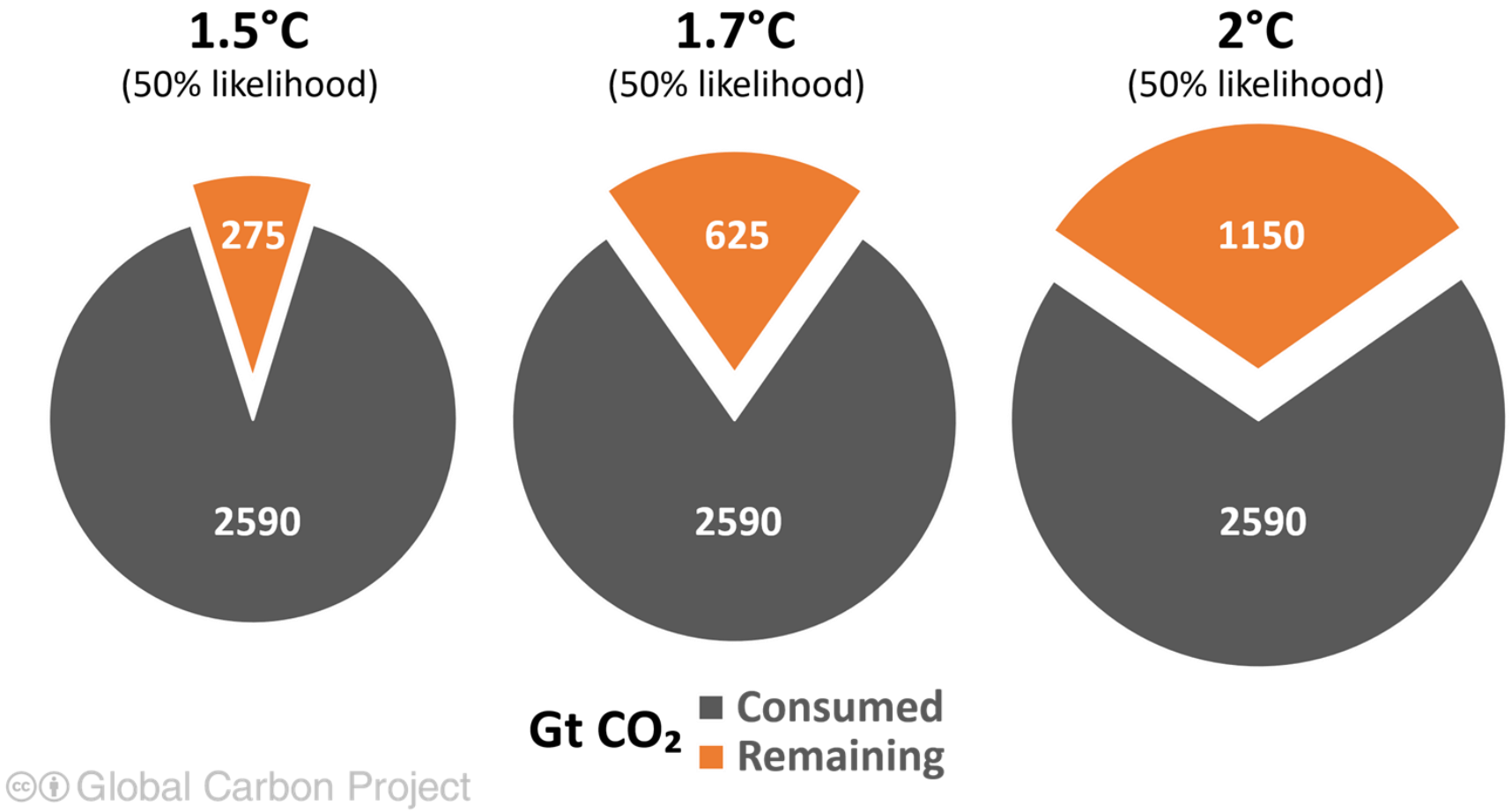
Current Nationally Determined Contributions (NDCs) are a drop in the ocean.

Level of ambition needed:
4 - 5 times for 2°C
7 – 8 times for 1.5°C

- https://unfccc.int/sites/default/files/2021-09/Fig7_NDC4Scencomparison_15Sep_0.jpg

land use, land-use change and forestry (*LULUCF*)

Remaining carbon budget



~7 years left

~ 15 years left

~ 28 years left

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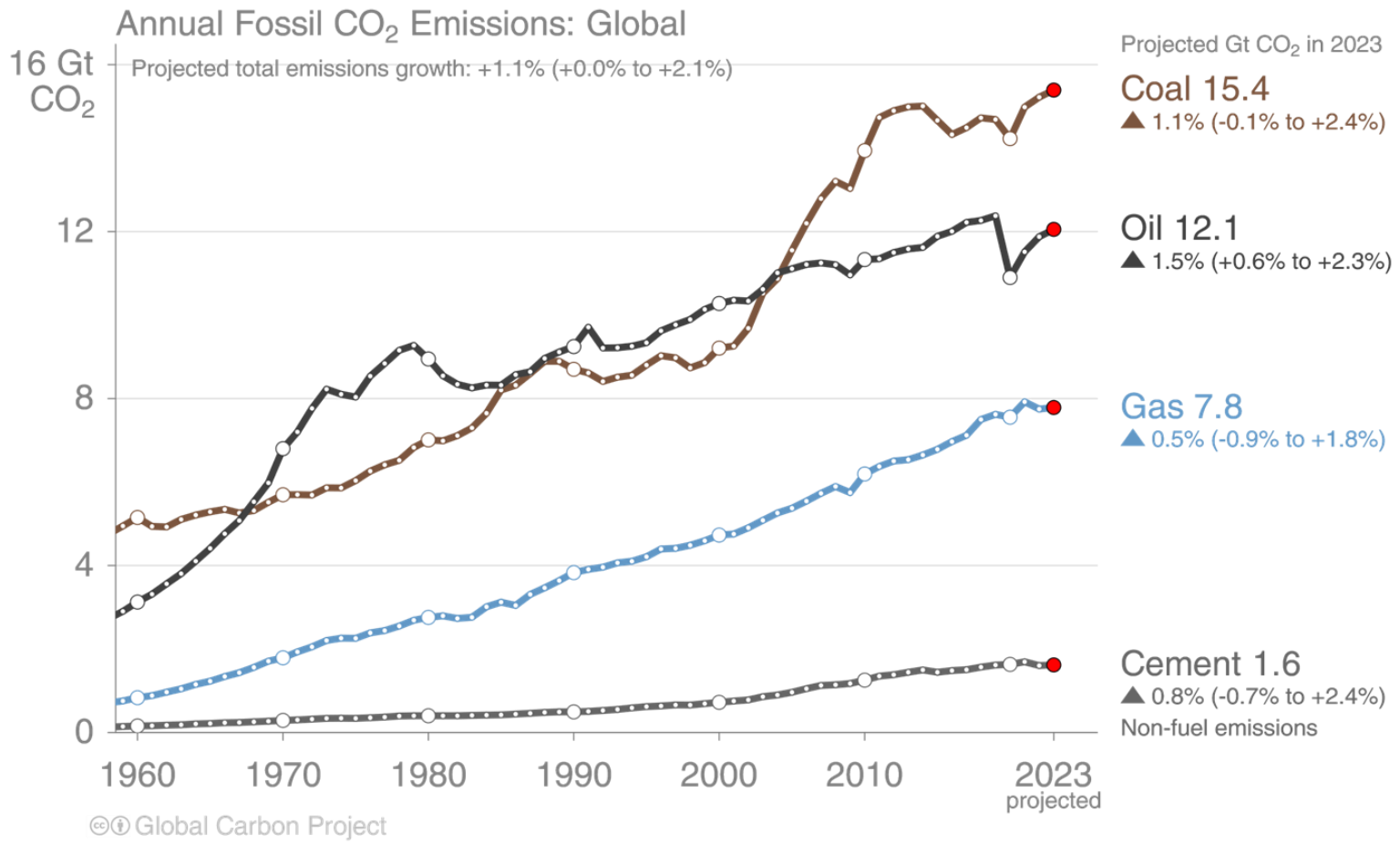
Fossil CO_2 emissions by source

Share of global fossil CO_2 emissions in 2023: coal (41%), oil (32%), gas (21%), cement (4%), flaring and others (2%, not shown)

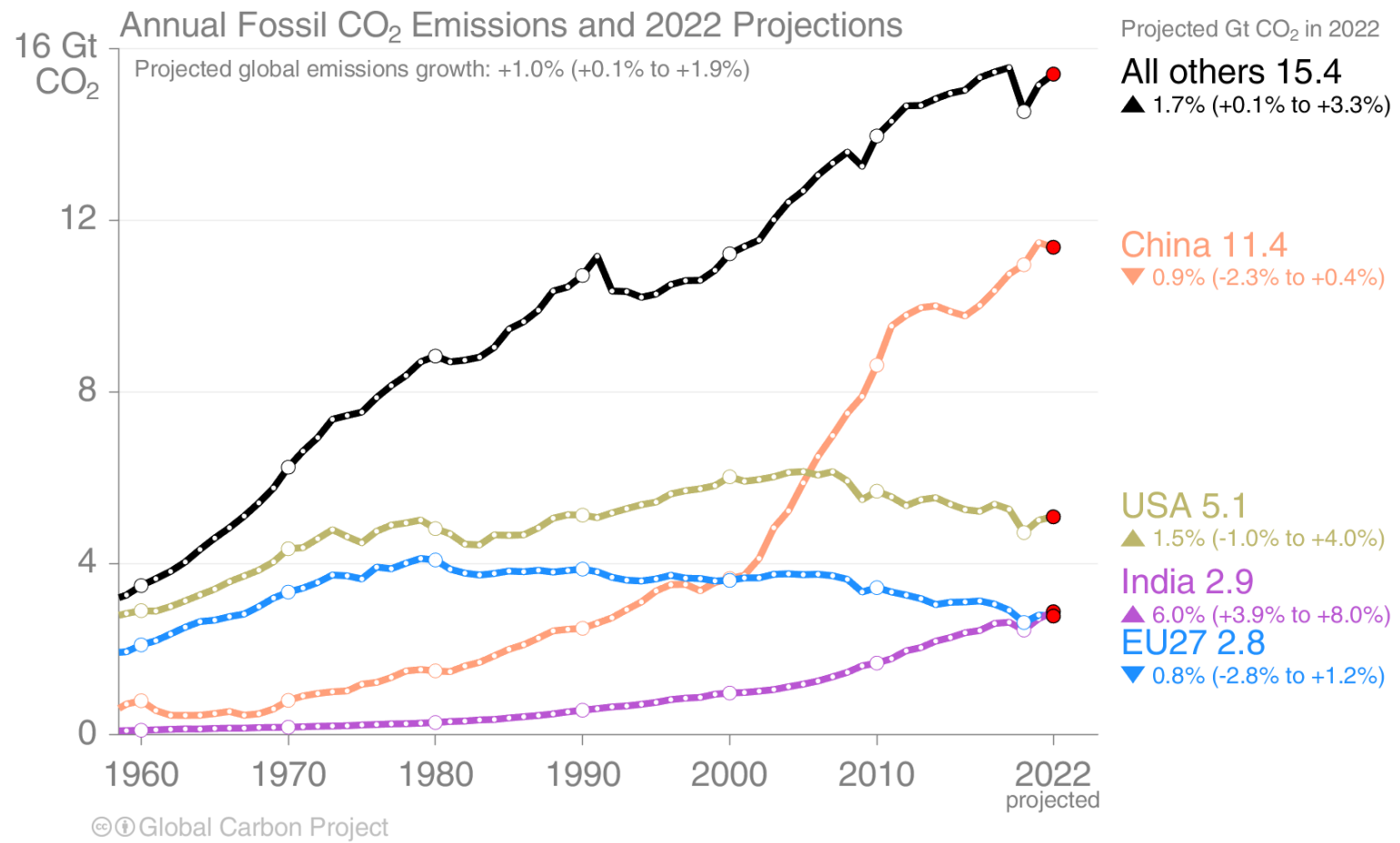
Fossil fuel emissions on the rise, still.



The 2023 projection is based on preliminary data and modelling.
Source: Friedlingstein et al 2023; Global Carbon Project 2023

Emissions per region

Global fossil CO_2 emissions are projected to increase by 1.0% [0.1% to 1.9%] in 2022



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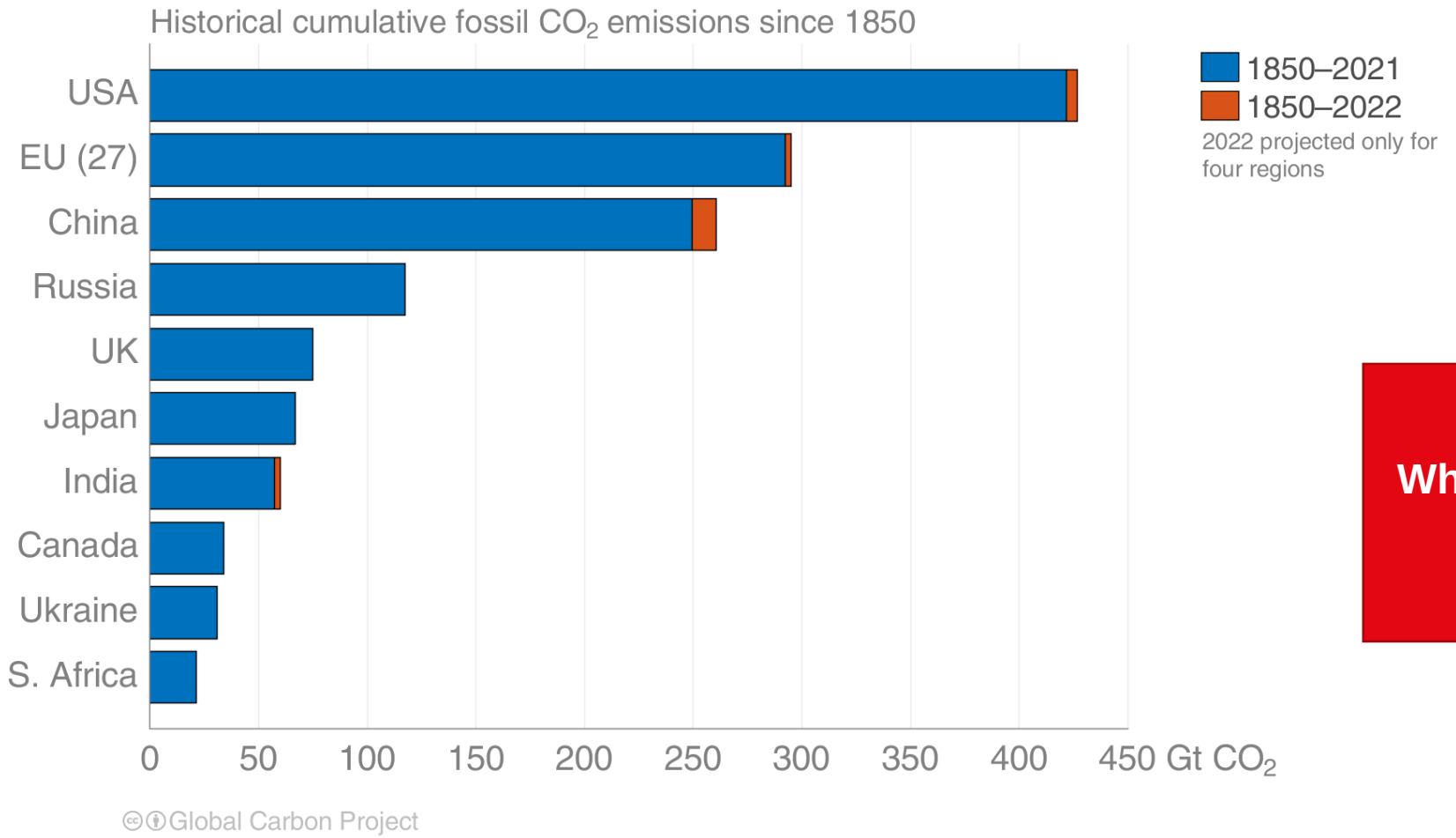
Historical cumulative fossil CO_2 emissions

The USA and EU have the highest accumulated fossil CO_2 emissions since 1850, but China is not far behind.



Who needs to act?

Calculated using territorial emissions.

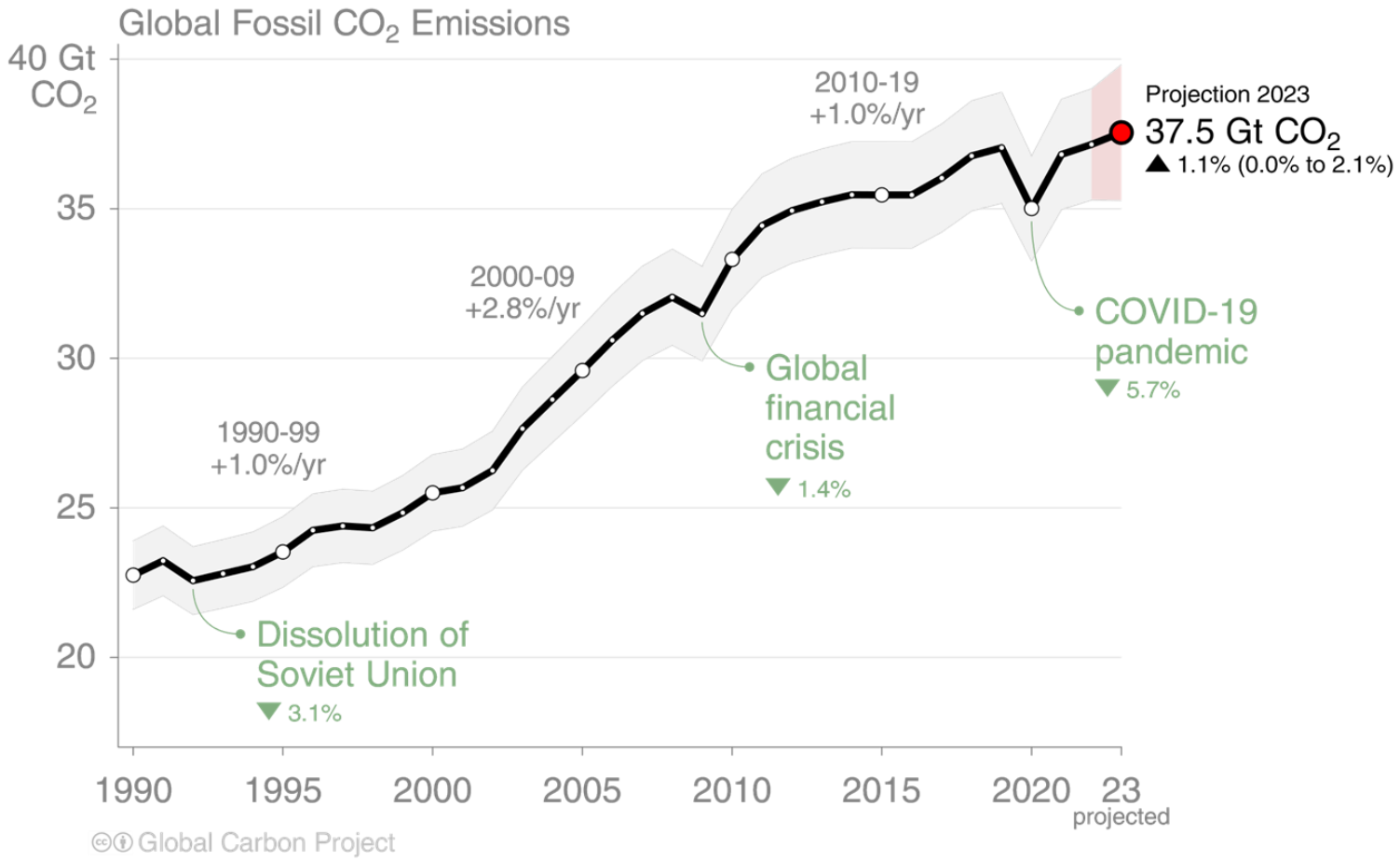
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions: 37.1 ± 2 $GtCO_2$ in 2022, 63% over 1990

Projection for 2023: 37.5 ± 2 $GtCO_2$, 1.1% [0.0% to +2.1%] higher than 2022

Covid was a tiny dent.



Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

When including cement carbonation, the 2022 and 2023 estimates amount to 36.4 ± 2 $GtCO_2$ and 36.8 ± 2 $GtCO_2$ respectively

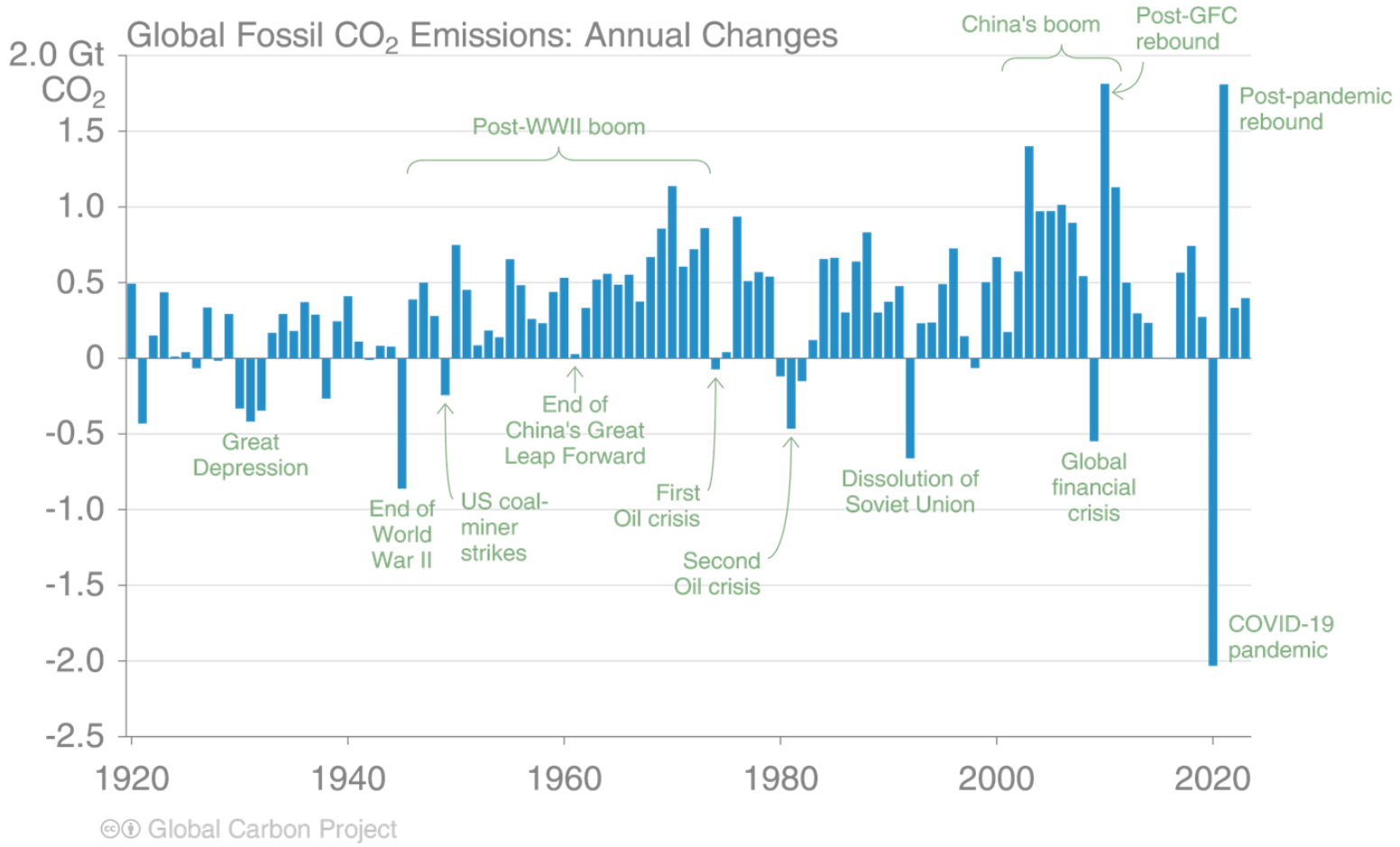
The 2023 projection is based on preliminary data and modelling.

Source: Friedlingstein et al 2023; Global Carbon Project 2023

Global fossil CO_2 emissions

For the last 100 years, it has generally taken a crisis to drive global emissions reductions.
To stabilise temperatures, intentional, planned, sustained global reductions must begin.

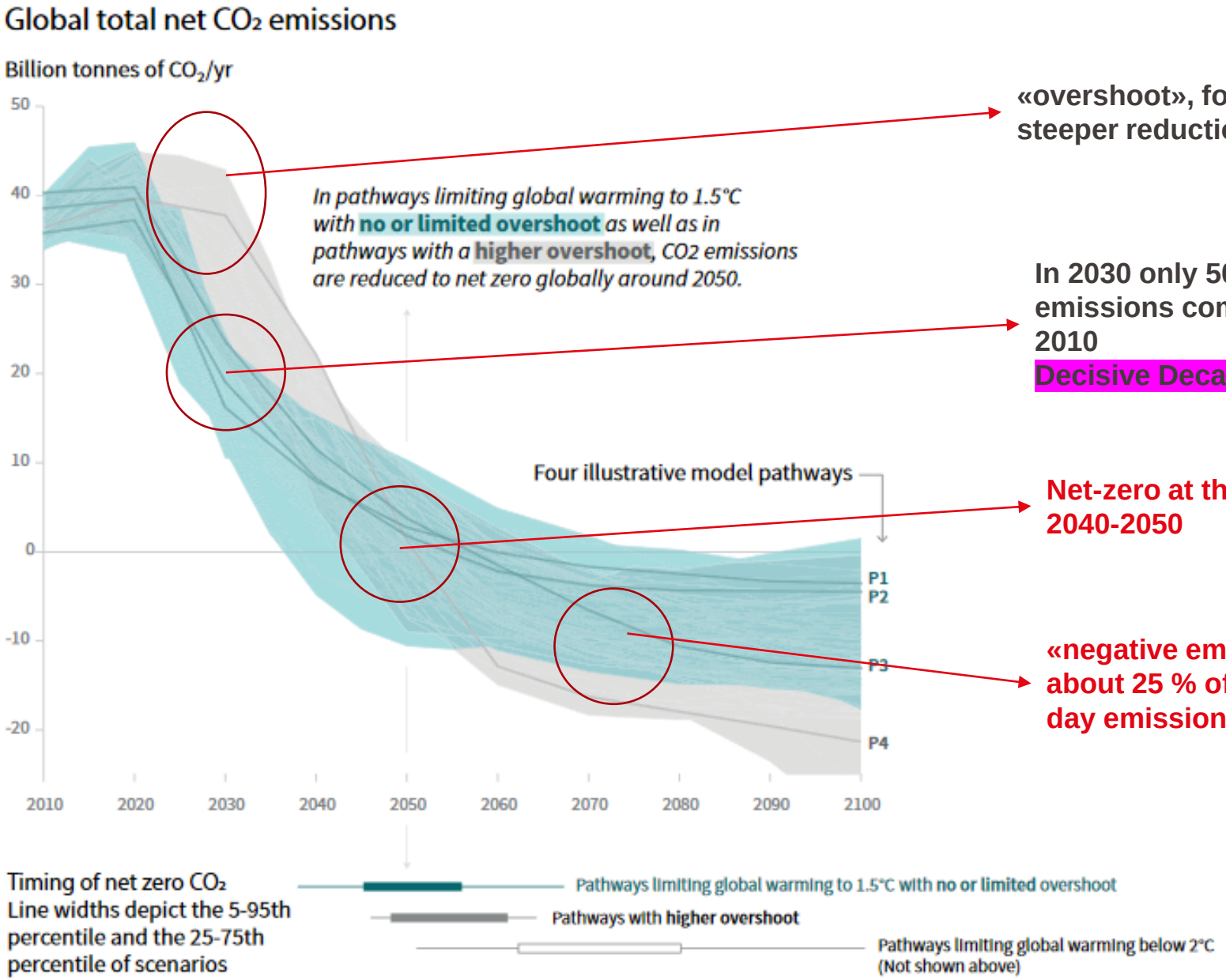
Humanity always needed a crisis to reduce emissions.



The 2023 projection is based on preliminary data and modelling.
Source: Friedlingstein et al 2023; Global Carbon Project 2023

Do we have the technology for net-zero and negative emissions?

Reducing emissions



«overshoot», followed by steeper reduction

In 2030 only 50 % of emissions compared to 2010
Decisive Decade

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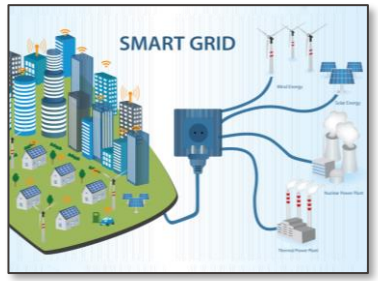
«negative emissions» about 25 % of present-day emissions!

IPCC, SP1.5

Relevant technology for mitigation

Solar

Fuel Cells



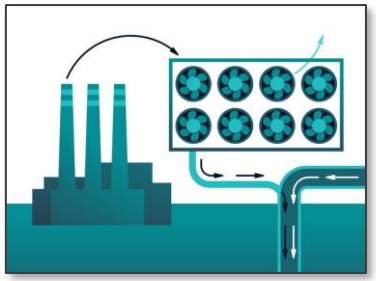
Smart Grids

Wind

Biogas

Alternative Fuels

Energy Storage



Carbon Capture

Small Modular Nuclear Reactors

Geo-thermal

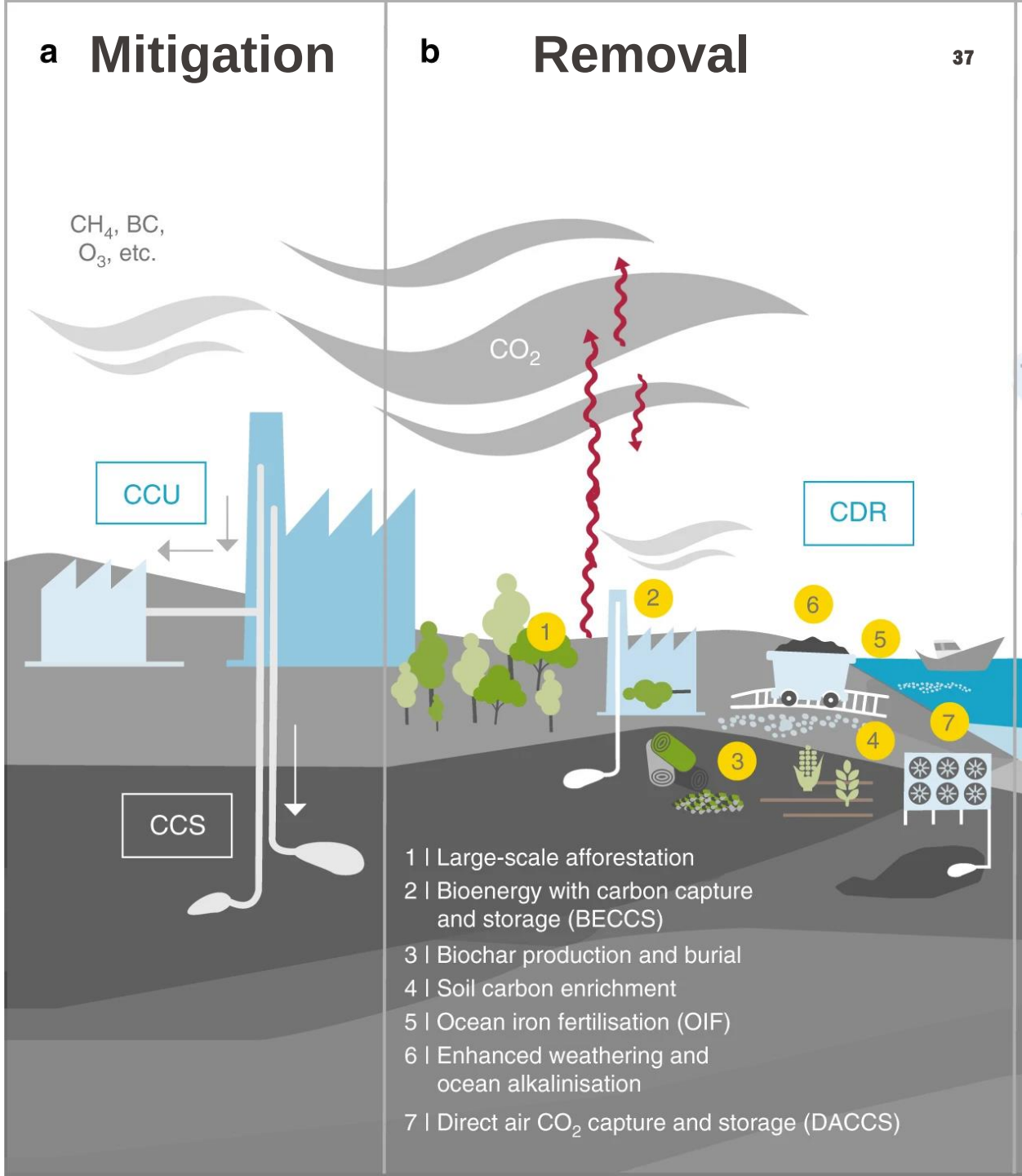
EU Net-Zero Industry Act
Goal: reaching at least 40% of the Union's deployment needs by 2030

Carbon removal options

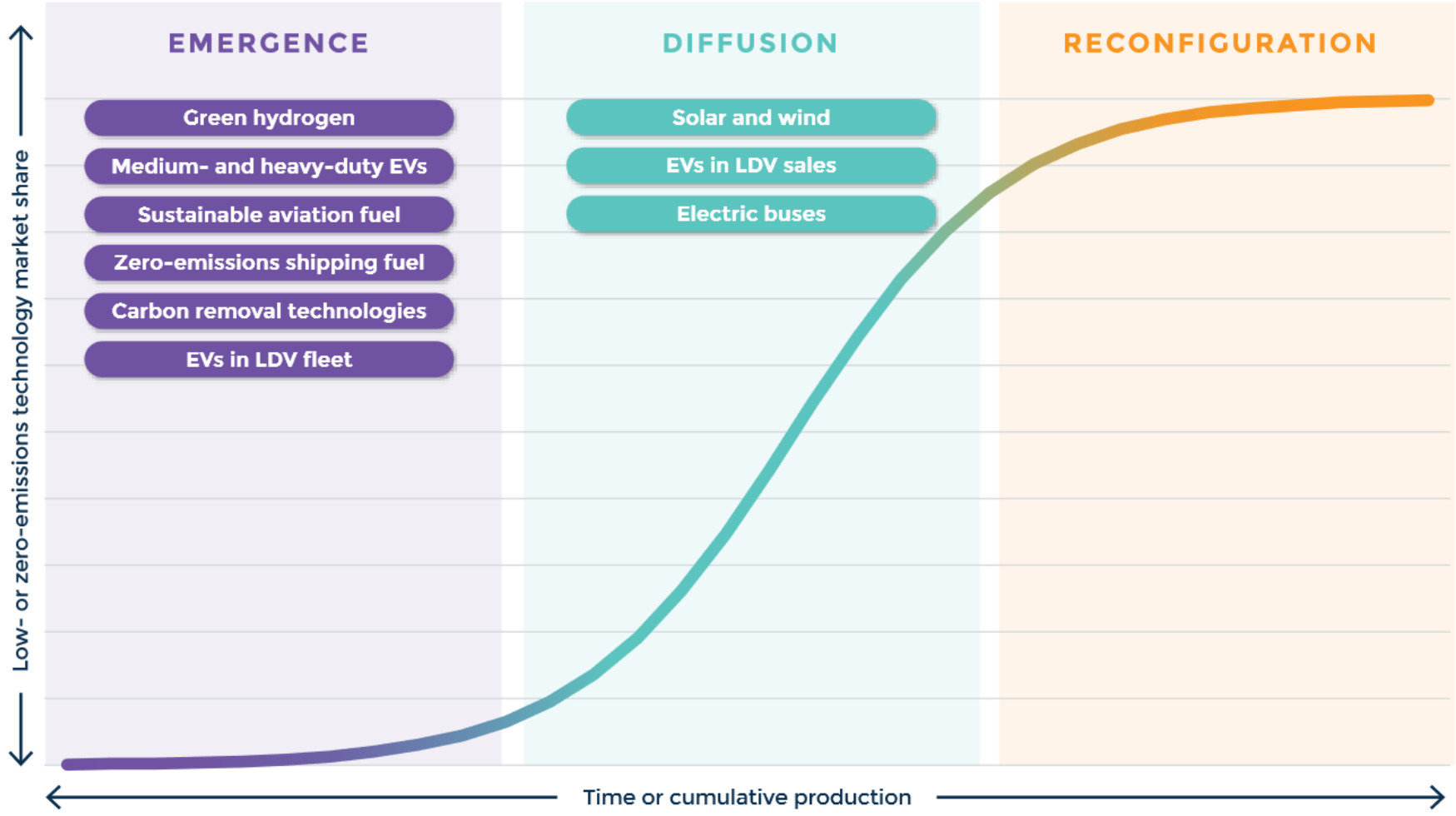
- **Mitigation**
  avoid emission of greenhouse gases through **carbon capture** and usage (CCU) and carbon capture and storage (CCS)

- **Carbon Dioxide Removal (CDR)**
  removes CO_2 **after** it has been emitted

- https://www.nature.com/articles/s41467-018-05938-3



Emission reduction with technology adoption



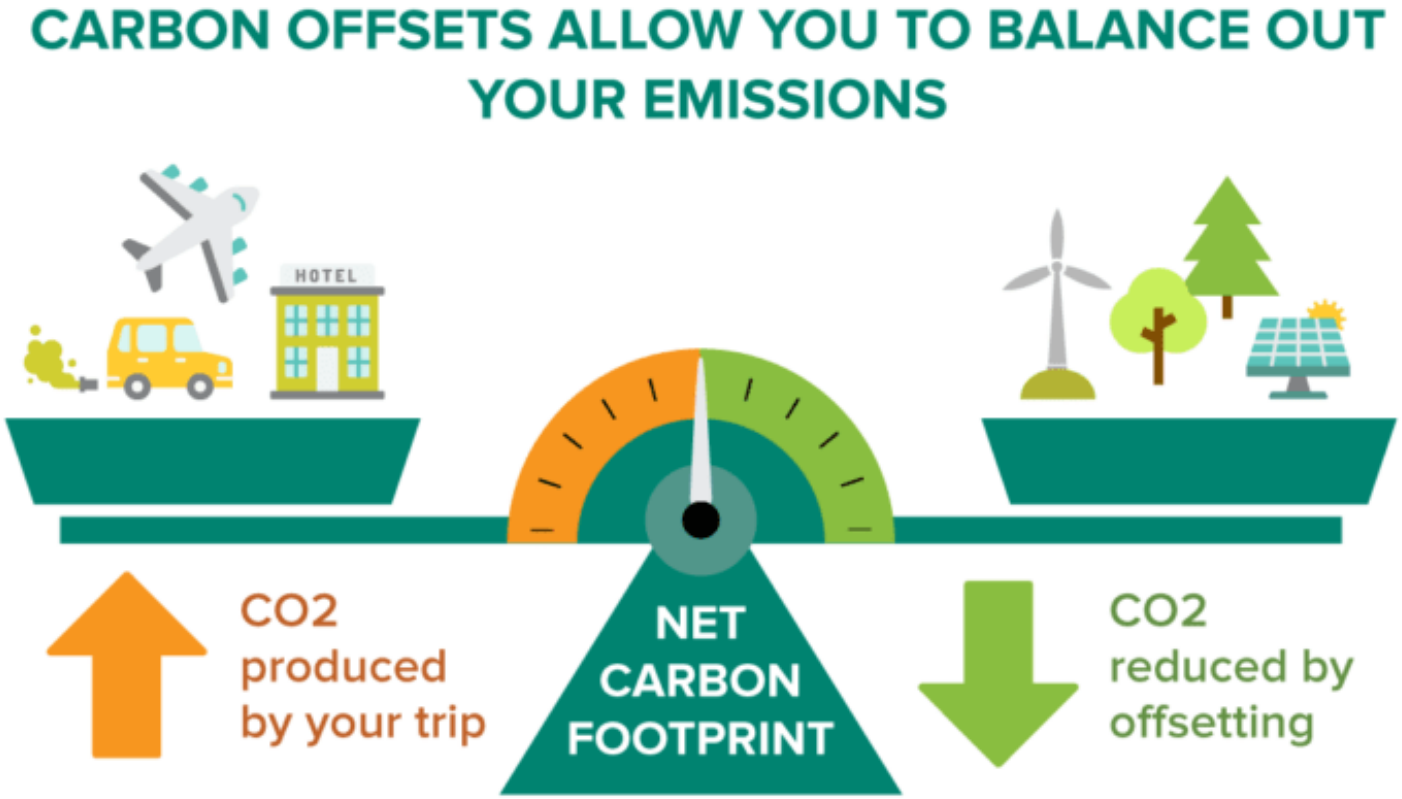
Note: EV = electric vehicle; LDV = light-duty vehicle. These labels include technologies that are directly tracked by our nine indicators that may follow an S-curve.

Source: Authors' judgment, based on Victor et al. (2019) and ETC (2020).

Are we fast enough?

- https://climateactiontracker.org/publications/state-of-climate-action-2021/

Carbon offsets?



Positive Aspects

- Transitional measure.
- Can leverage projects with private money that governments would not support.

Negative Aspects

- 90% of carbon offset projects fail.
- Often used as license to pollute.

Carbon offsets don't really work yet!

Any shortcut?

That we want?

Solar Radiation Management?

General idea

- keep solar radiation from being absorbed on Earth
- → reflect it to space

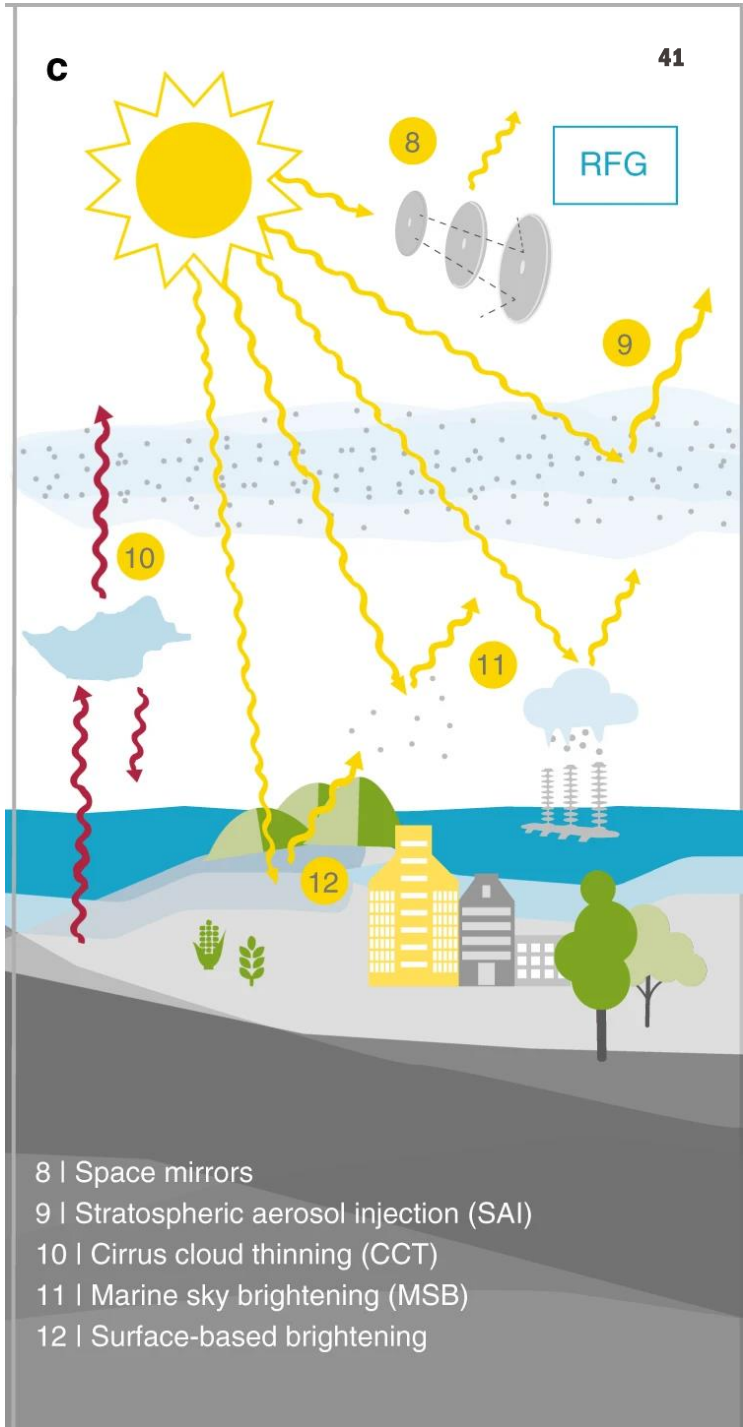
Options

- Space mirrors
- Stratospheric aerosol injection (mimicking a volcano)
- Cirrus cloud thining
- Marine sky brightening
- Surface-based brightening

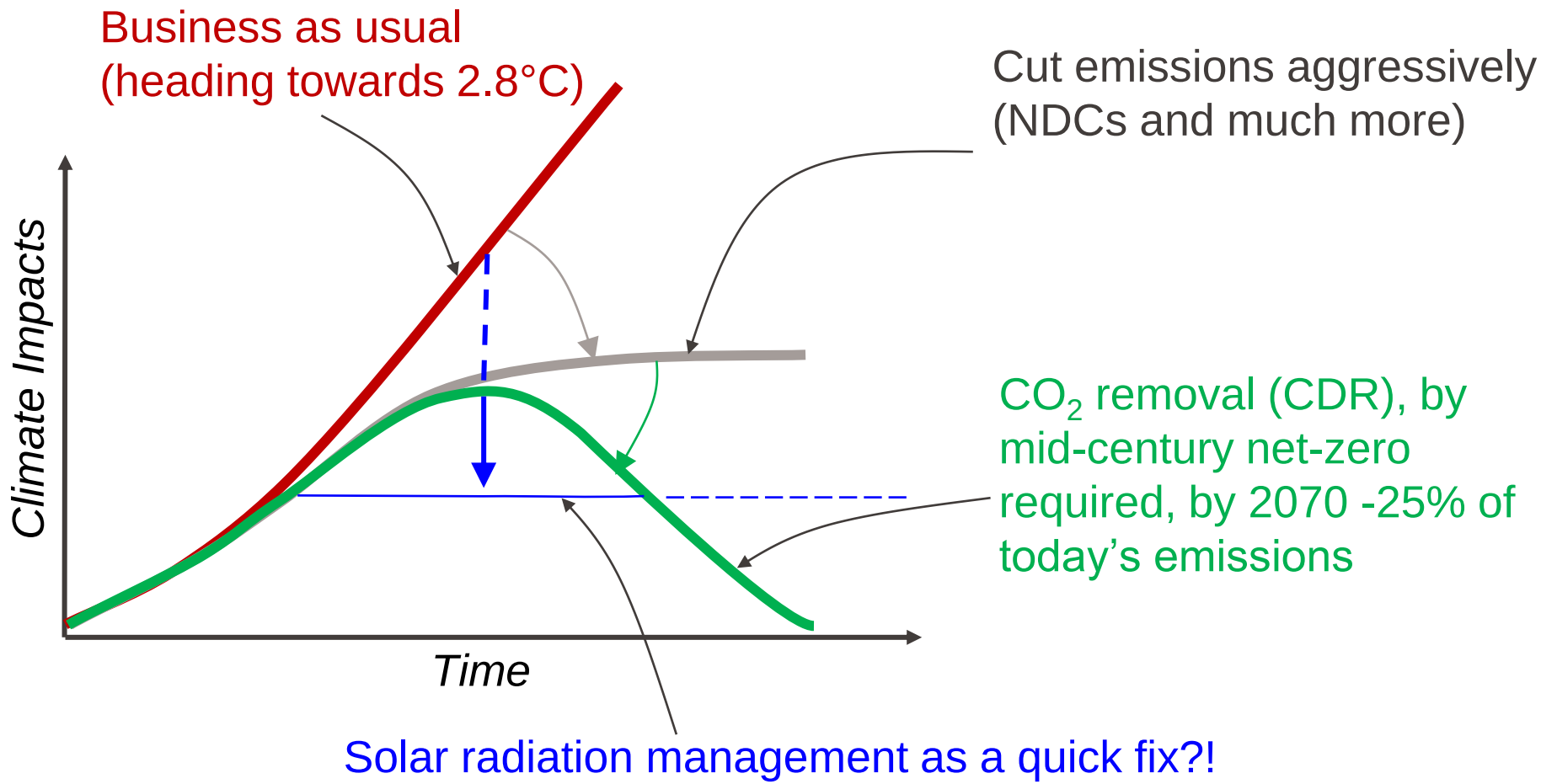
Concerns

- Adverse effects not fully known
- No governance, no legal framework → Who decides?
- Many other…

- https://www.nature.com/articles/s41467-018-05938-3



Solar radiation management: A last resort?



SHEPHERD, J 2010 The 'napkin diagram' of multiple responses to climate change http://jgshepherd.com/wp-content/uploads/2011/01/Napkin-diagram.pdf

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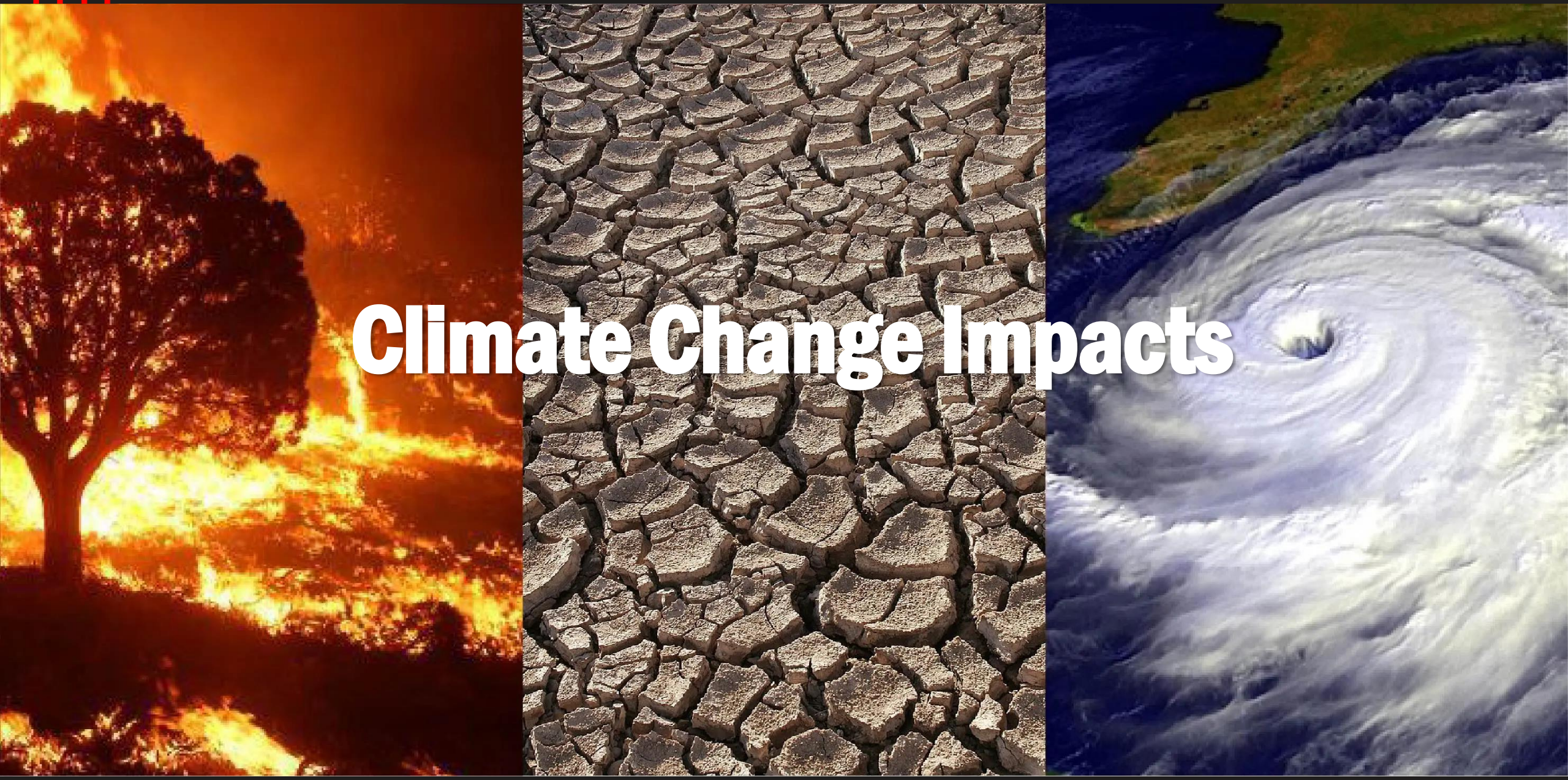
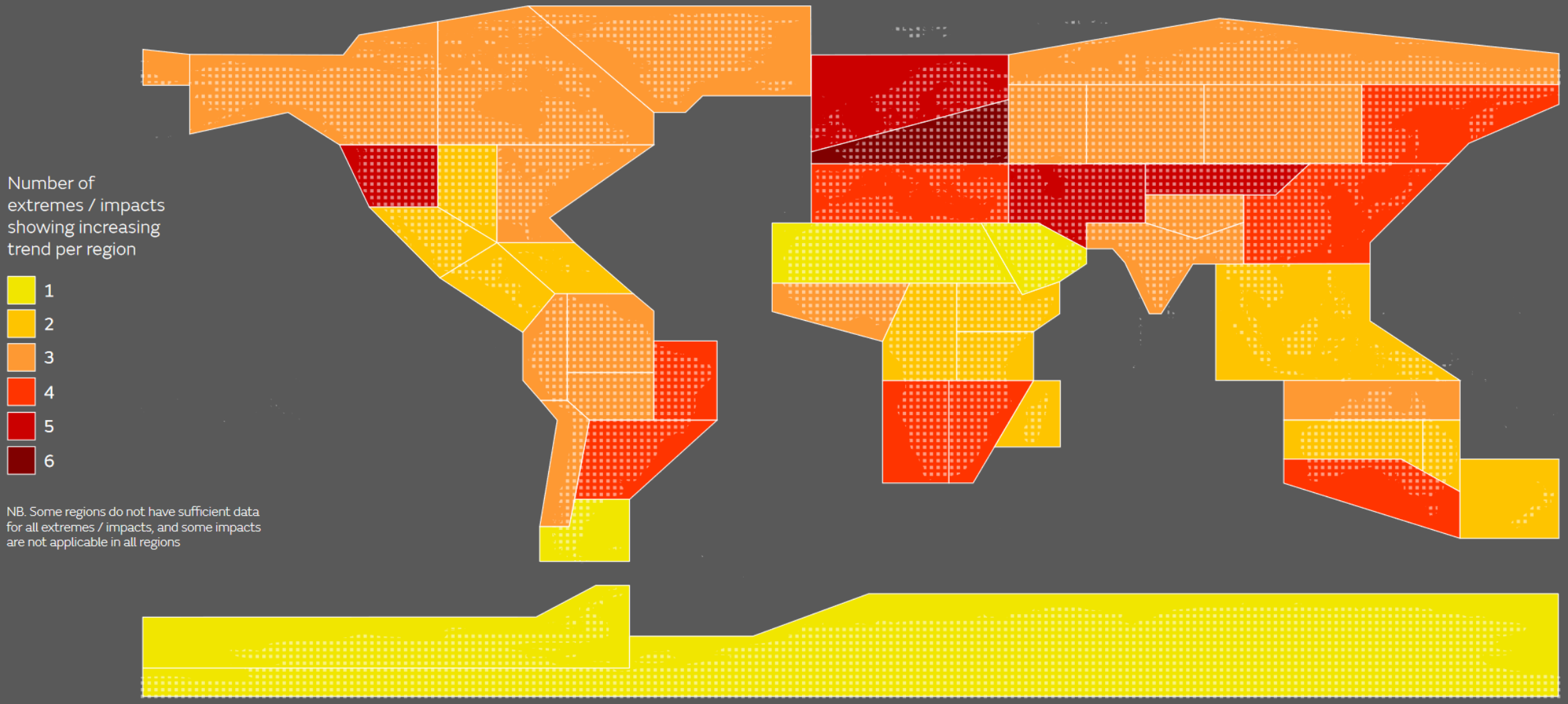


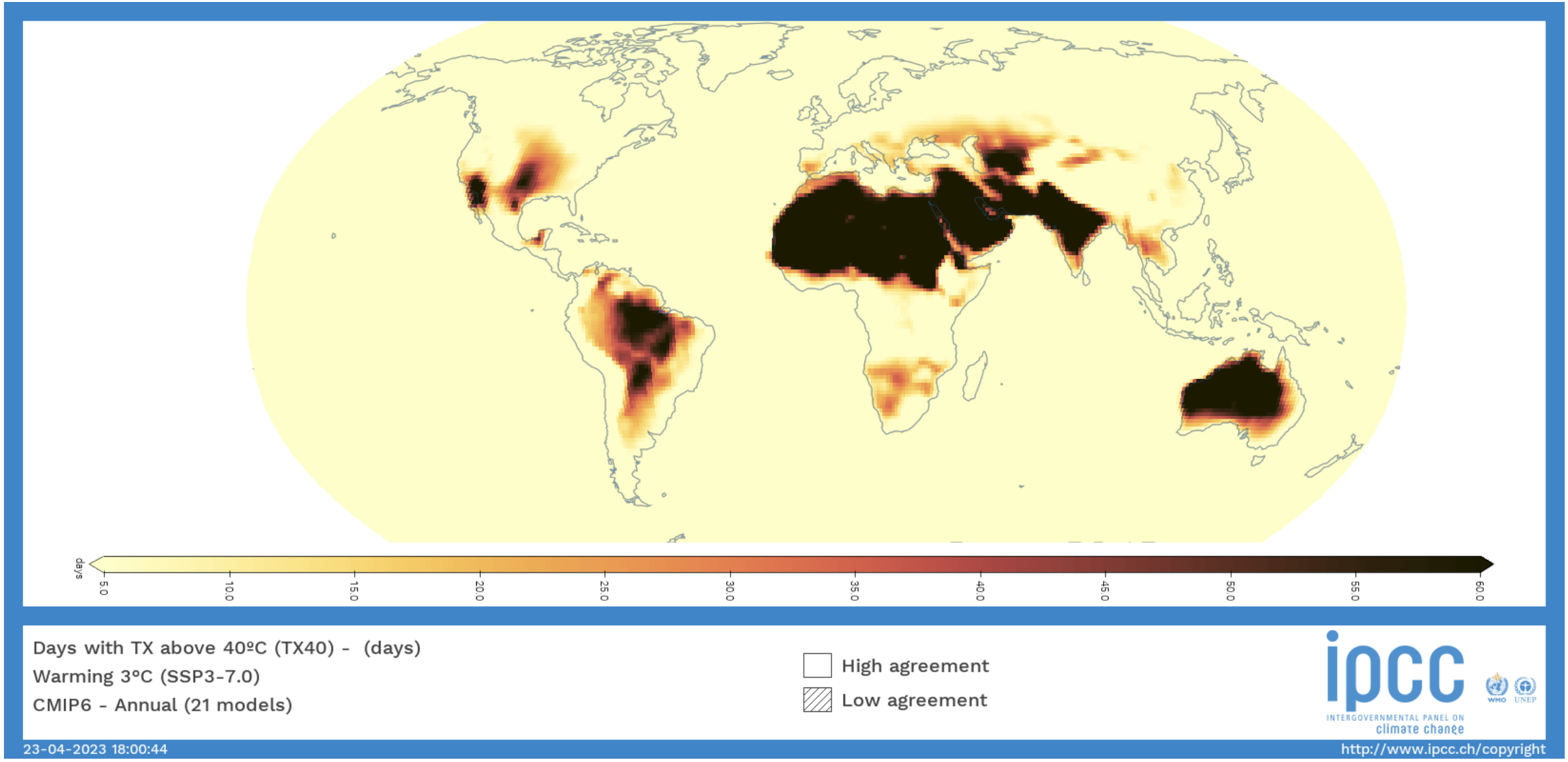
Climate Change Impacts

Met Office

Multiple changes in weather extremes and climate impacts

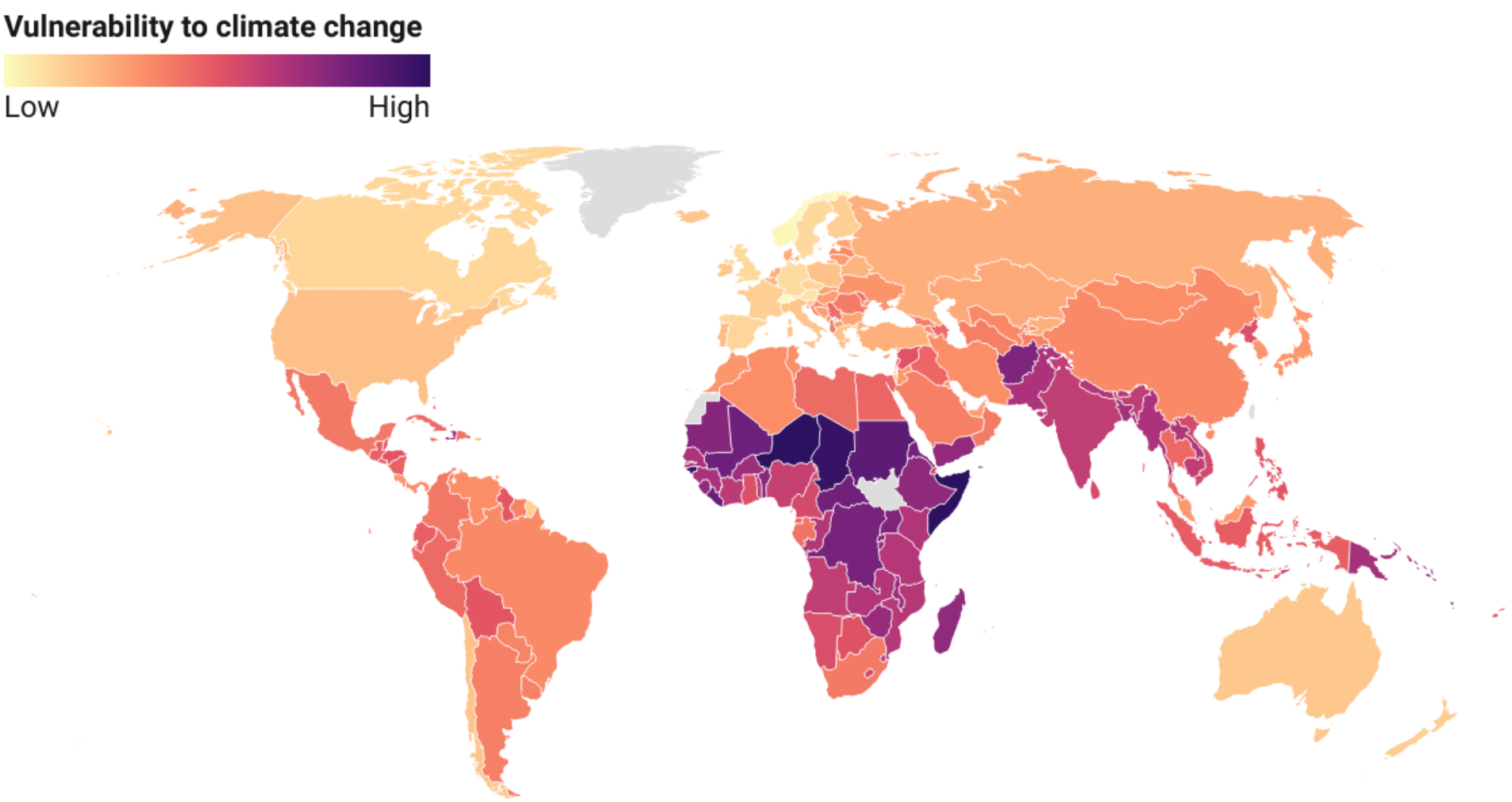


Days > 40°C @ 3°C warming



The countries most vulnerable to climate change

The Notre Dame Global Adaptation Initiative index gauges countries' vulnerability based on their exposure, sensitivity and ability to adapt to the negative impacts of climate change.

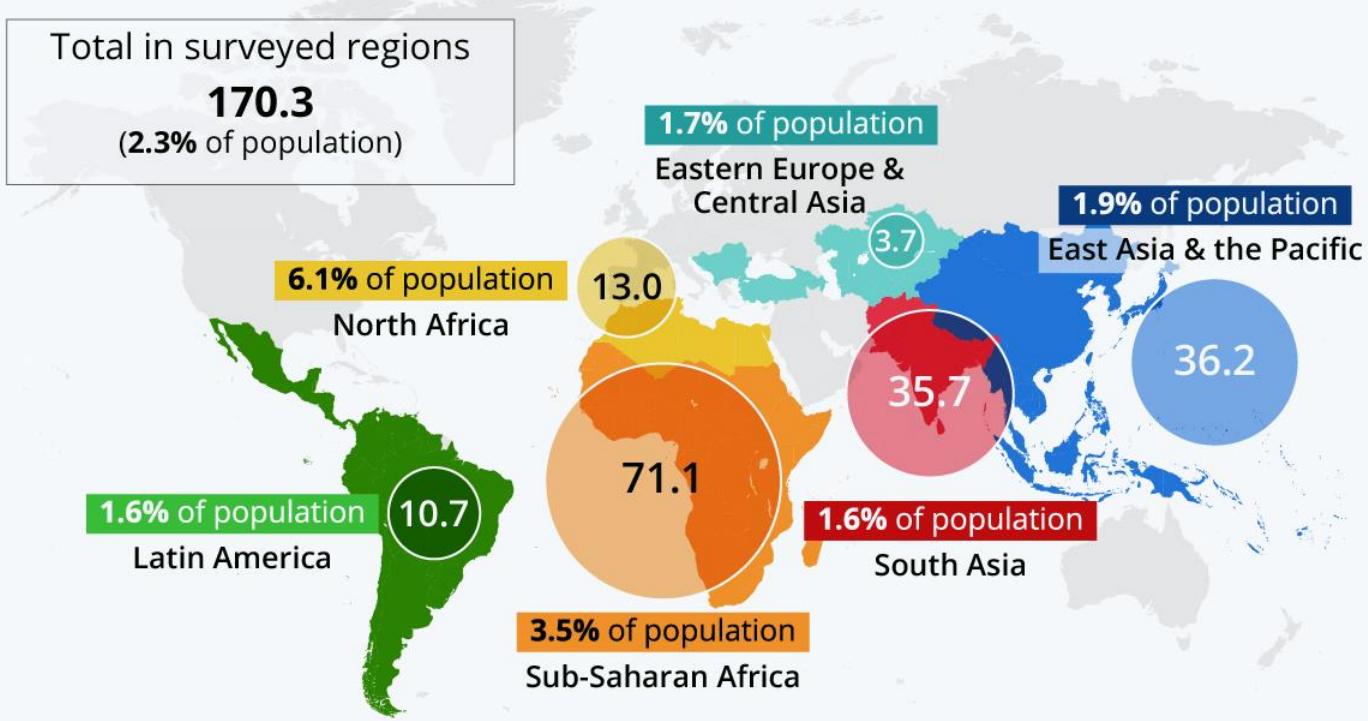


Darker colors reflect greater vulnerability; gray indicates no data available

Map: The Conversation/CC-BY-ND • Source: ND-GAIN • Created with Datawrapper

Climate Change, the Great Displacer

Average number of internal climate migrants by 2050 per region (in millions)*



* Modeled on pessimistic reference = High emission & unequal development scenarios concerning water availability, crop productivity and sea-level rise

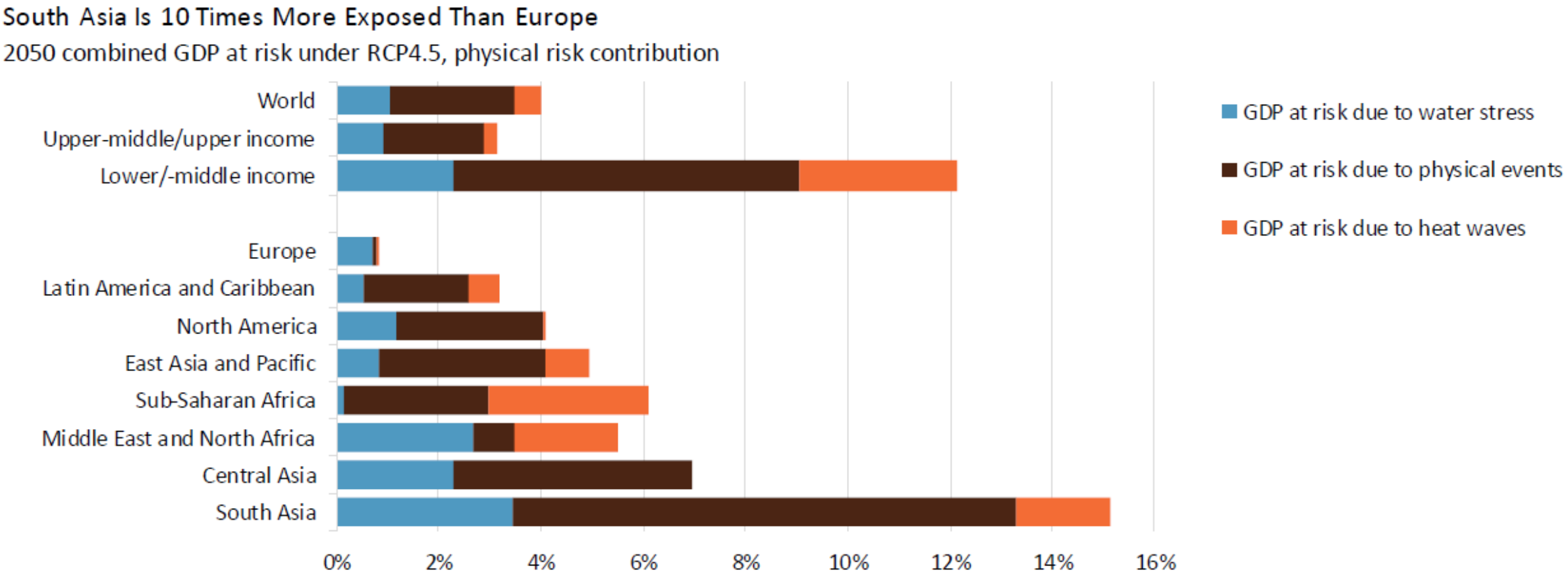
Source: World Bank

statista

The climate crisis is a humanitarian crisis

Yearly displacements:
> 20 Millions
(UN Refugee Agency)

Economic impact



Note: Countries' income and regional classification is based on World Bank. Sources: S&P Global Ratings, Trucost (2022).

Anything else to worry about?

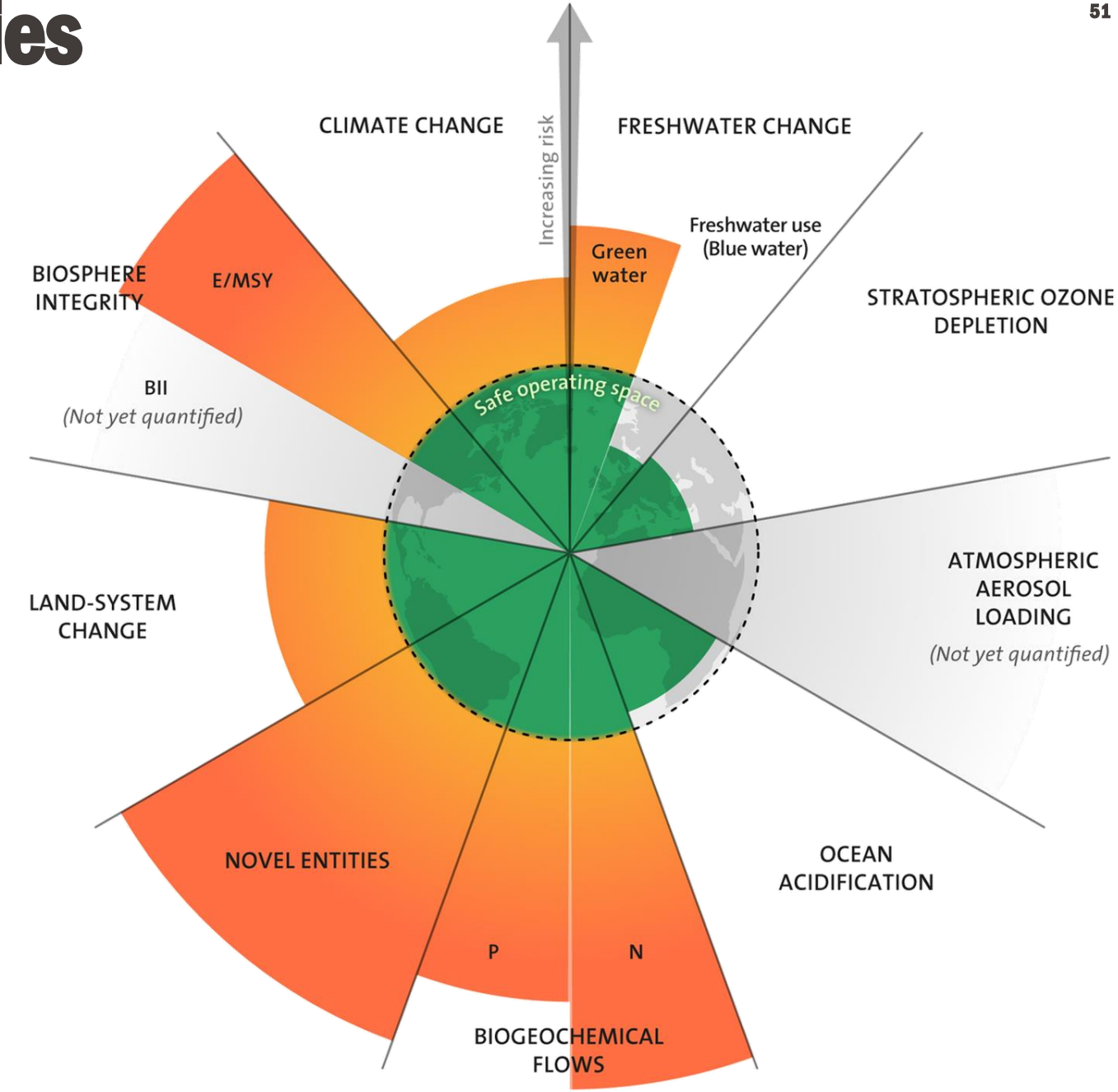
9 Planetary Boundaries

"Anthropogenic pressures on the Earth System have reached a scale where ***abrupt global environmental change can no longer be excluded****.*

We propose a new approach to global sustainability in which we define ***planetary boundaries within which we expect that humanity can operate safely****.*

Transgressing *one or more planetary boundaries may be* ***deleterious or even catastrophic*** *due to the risk of crossing thresholds that will trigger* ***non-linear, abrupt environmental change*** *within continental- to planetary-scale systems."*

Rockström et al. (2009)



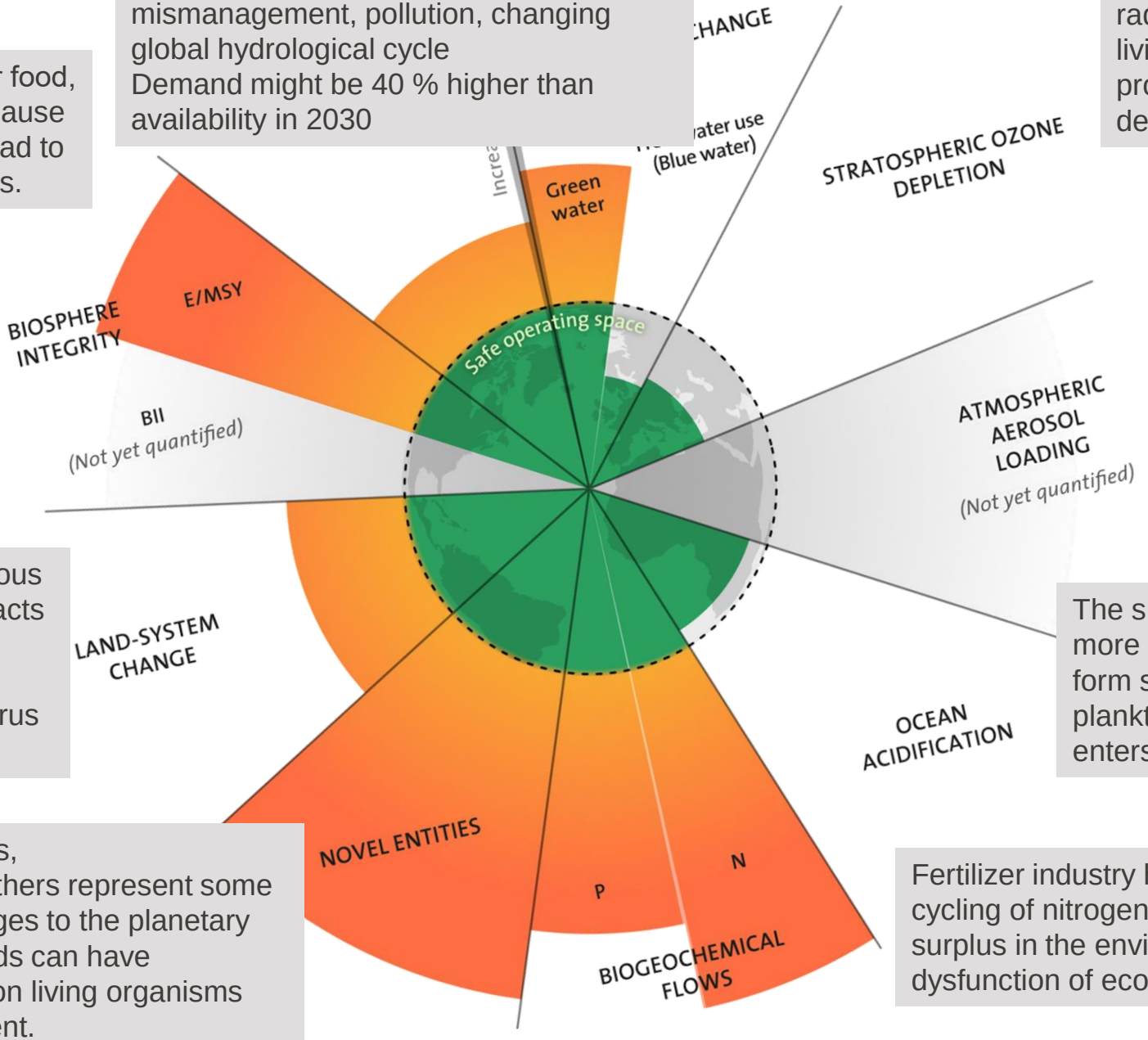
Wang-Erlandsson et al. (2022)

“Great extinction”. Demand for food, water, and natural resources cause severe biodiversity loss and lead to changes in ecosystem services.

Green water: precipitation; Blue water: rivers, lakes, ground water; Triple crisis: mismanagement, pollution, changing global hydrological cycle
Demand might be 40 % higher than availability in 2030

The ozone hole lets lethal UV radiation pass (→ damage of living creatures). The Montreal protocol banned ozone-depleting substances.

Genetic diversity: Extinction rate measured as E/MSY (extinctions per million species-years)
Functional diversity: BII (Biodiversity Intactness Index)



Aerosols change Earth’s radiative balance and the hydrological cycle (cloud formation). The are also air pollutants and cause millions of premature deaths annually.

A driving force behind the serious reductions in biodiversity, impacts on water flows and
on biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements.

The surface ocean is already 30 % more acidified. Certain species cannot form shells, corals, shellfish and plankton have trouble to survive. This enters the global ecoystem dynamics.

Synthetic chemical compounds, microplastics,antibiotics and others represent some of the key human-driven changes to the planetary environment. These compounds can have potentially irreversible effects on living organisms and on the physical environment.

Fertilizer industry has drastically changed the cycling of nitrogen (N) and phosphorous (P). Their surplus in the environment leads to pollution and dysfunction of ecosystems.

«Planetary» Emergency in a nutshell

1. We are extremely close to our target threshold.
2. (Drastic) actions are needed now.
3. Humanity is faced with a technological, political and behavioral challenge never encountered before.

We cannot wait for solutions, we must drive solutions.

Thank you for your attention!

At stake →

Questions & Discussion

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