

Introduction -- Science, Economics, & Policy

Recorded Session #1

Robert N. Stavins

A.J. Meyer Professor of Energy & Economic Development

Climate Change Policy: Economics and Politics

Harvard Kennedy School Executive Education

Cambridge, Massachusetts, USA

October 16 - 20, 2024

Essential Science of Global Climate Change

The Greenhouse Effect: water vapor, CO₂, *methane*, nitrous oxide, CFCs

- **Emissions**

- Energy generation (coal, petroleum, natural gas) → CO₂
- Other industrial, commercial, & residential CO₂
- Transportation CO₂
- Deforestation CO₂
- *Methane*, nitrous oxide, CFCs

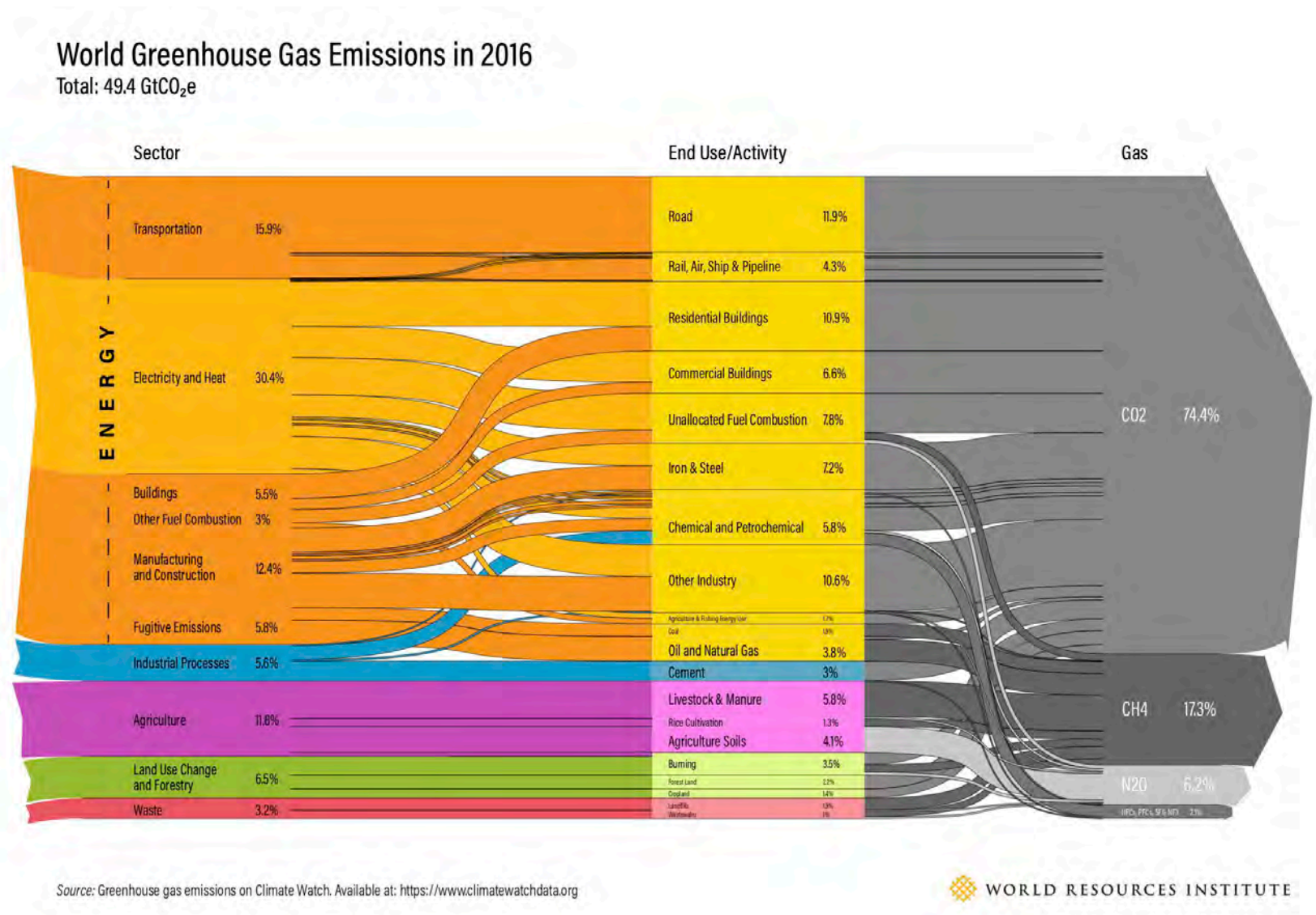
- **Sequestration**

- Biological carbon sequestration (land-use changes)
- Carbon capture and storage (later)

- **Scientific Uncertainty?**

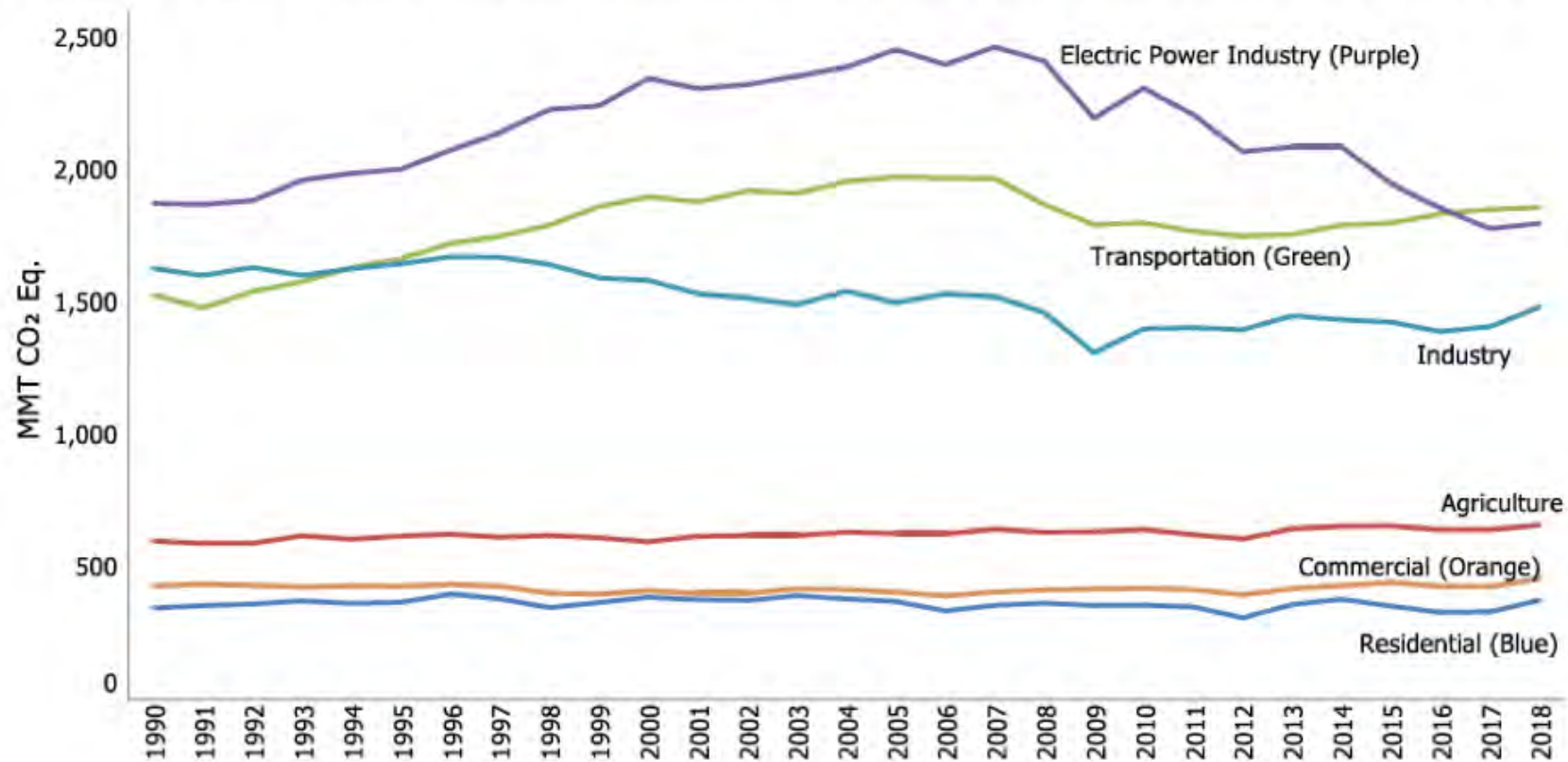
- Impact of increased concentrations on global mean temperatures
- Impacts on regional weather patterns

Sectors and End Uses/Activities Leading to Greenhouse Gas Emissions



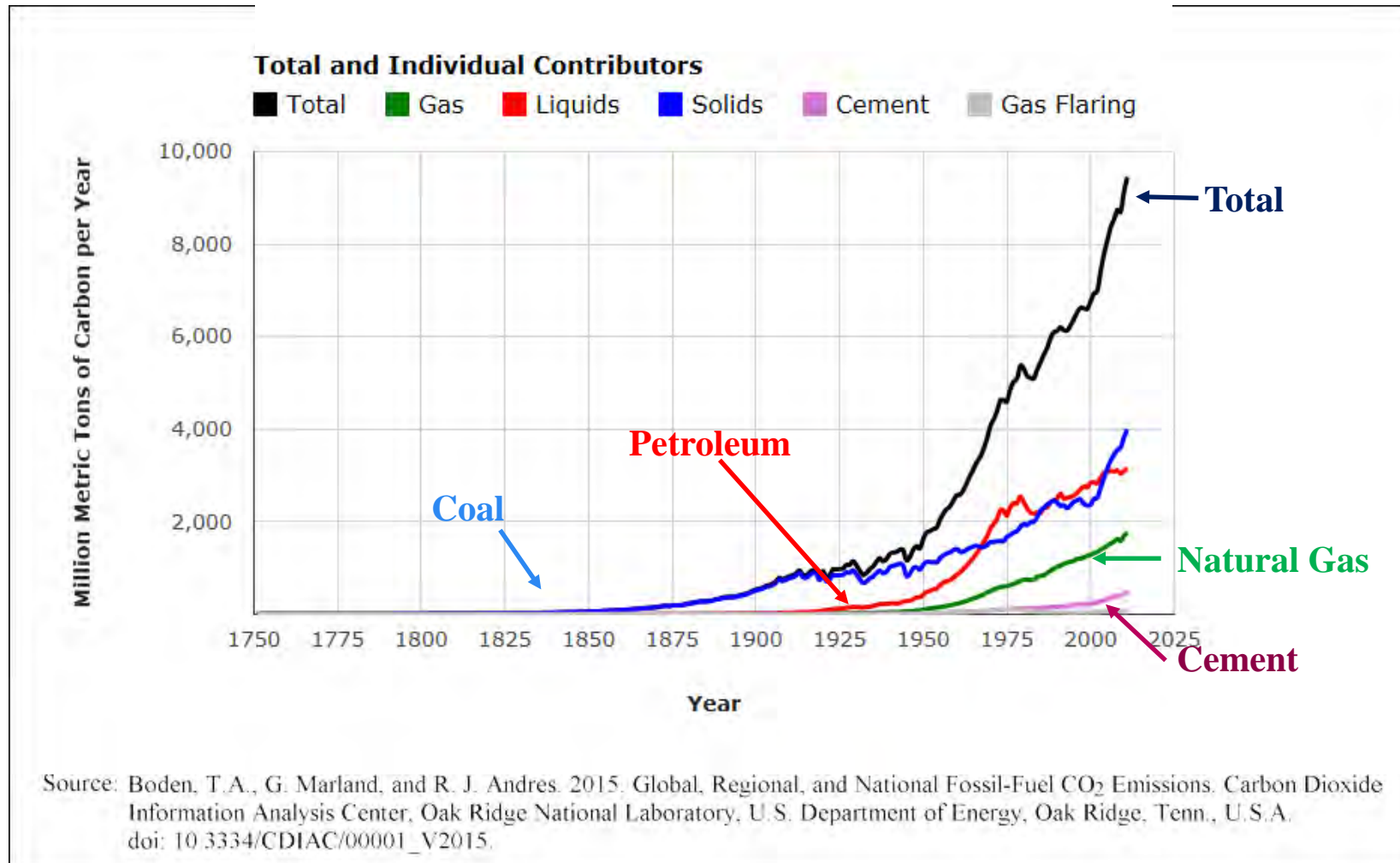
Note: exhibits 100-year global warming potential)

U.S. Greenhouse Gas Emissions from Economic Sectors

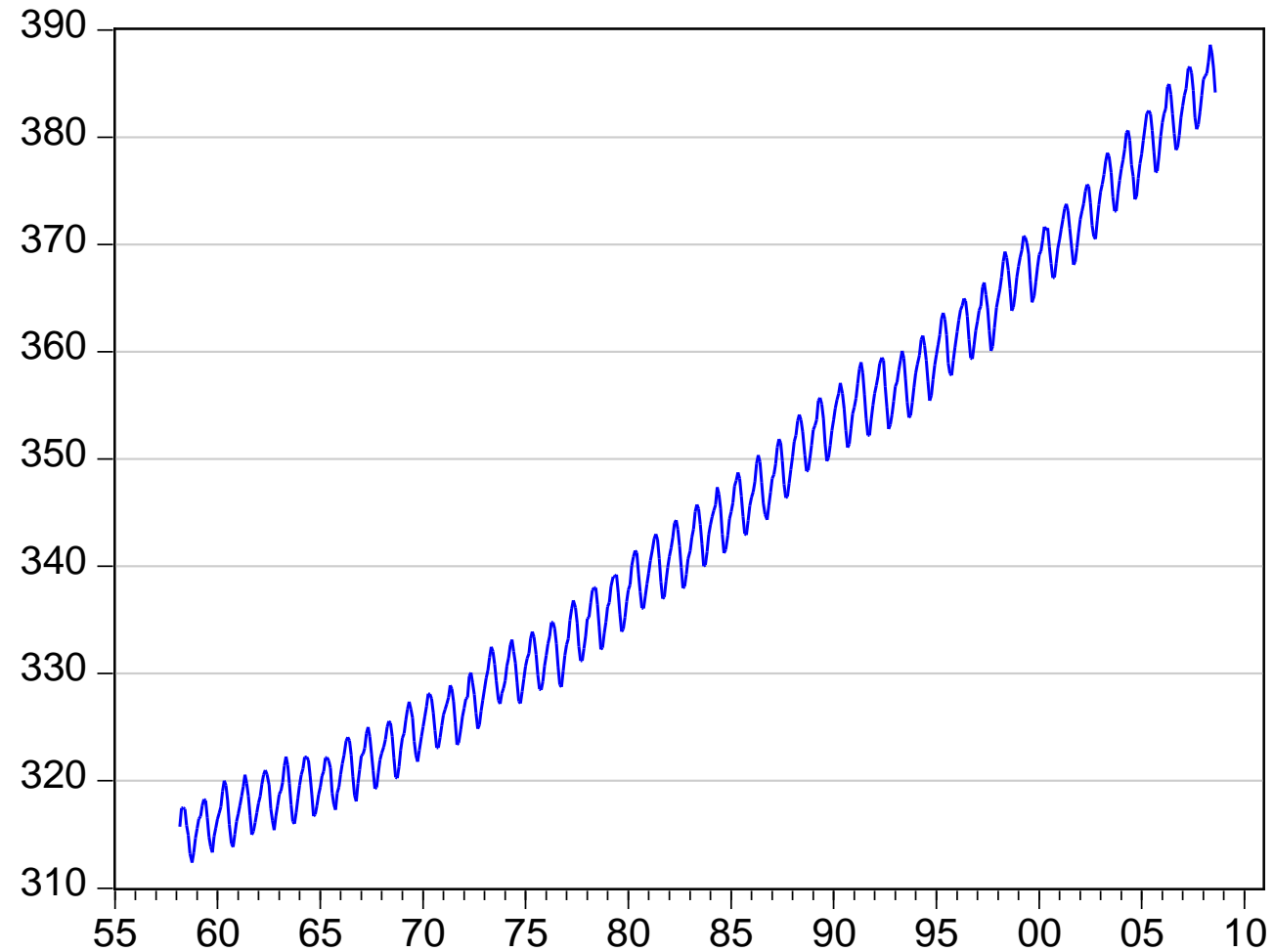


Source: [US GHG Inventory of Greenhouse Gas Emissions and Sinks](#)

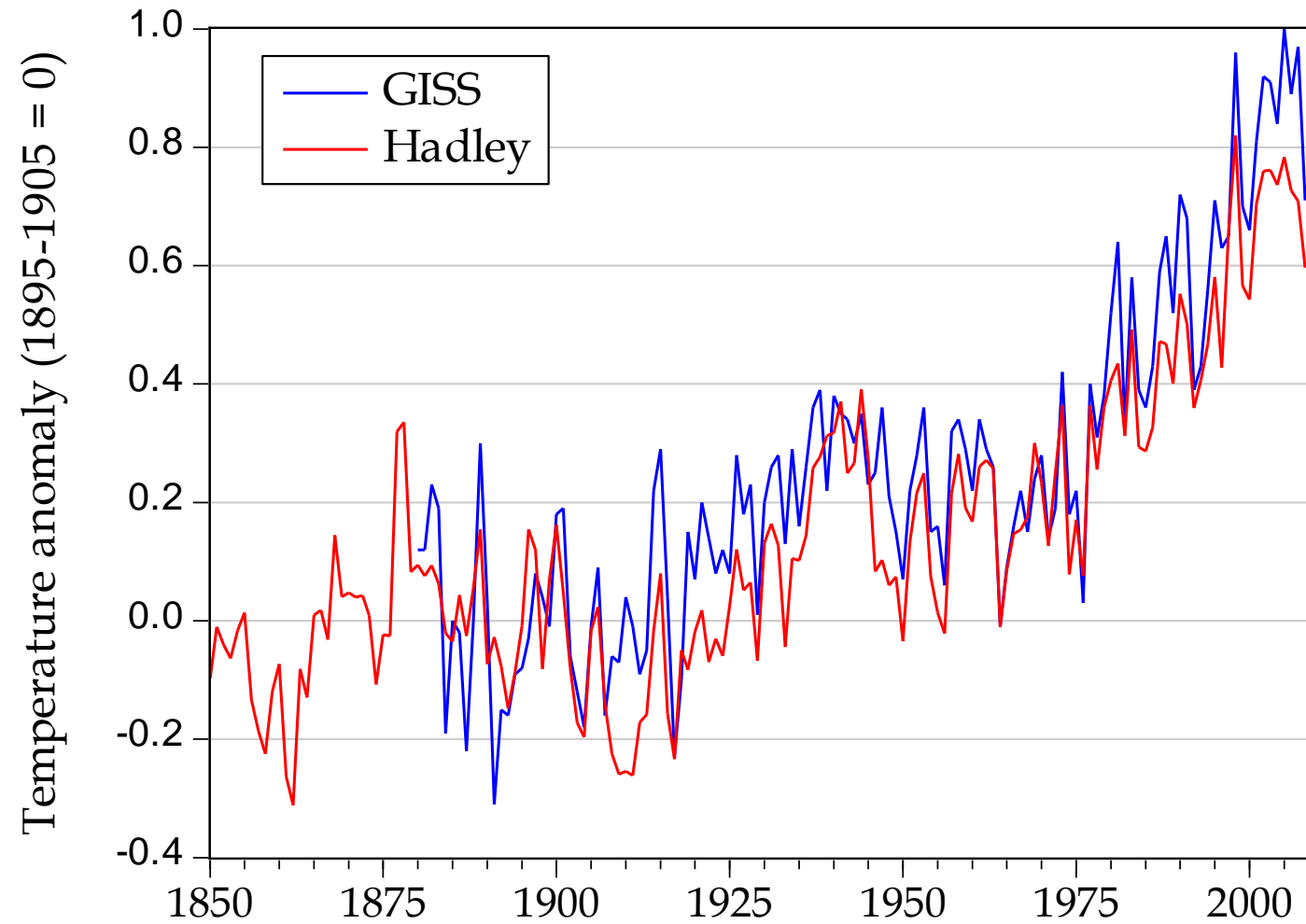
Annual World CO₂ Emissions, 1750-2010, from Coal, Petroleum, Natural Gas, and Cement Production



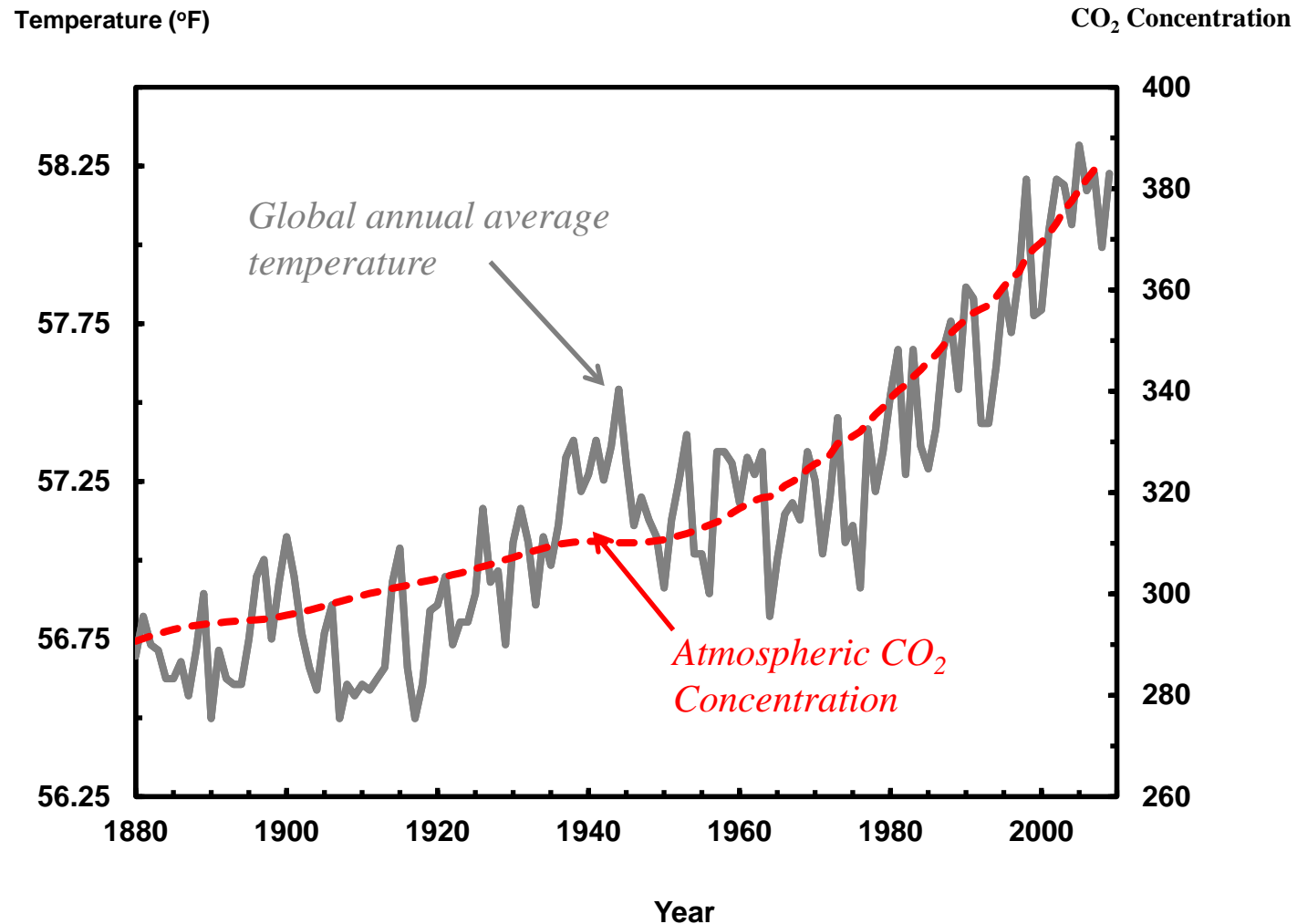
CO₂ Concentrations at Mauna Loa, Hawaii, 1957-2008



Temperature Records, 1850-2008



Global Temperature and Carbon Dioxide Concentrations 1880–2010



Impacts

The Regional Picture

The lists here indicate just some of the disturbing effects, beyond those enumerated in the discussion at the left, that Working Group II foresees in various parts of the world over the coming century. The group made most of these predictions with high or very high confidence. Find more details at www.ucar.edu/news/features/climatechange/regionalimpacts.jsp and at the IPCC Web site (www.ipcc.ch).

North America

- In the western mountains, decreased snowpack, more winter flooding and reduced summer flows
- An extended period of high fire risk and large increases in area burned
- Increased intensity, duration and number of heat waves in cities historically prone to them
- In coastal areas, increased stress on people and property as climate interacts with development and pollution

Europe

- Increased risk of inland flash floods
- In the south, more health-threatening heat waves and wildfires, reduced water availability and hydropower potential, endangered crop production and reduced summer tourism
- In the central and eastern areas, more health-threatening heat waves and peatland fires and reduced summer rainfall and forest productivity
- In the north, negative impacts eventually outweigh such initial benefits as reduced heating demand and increased crop yields and forest growth

Asia

- Increased flooding, rock avalanches and water resource disruptions as Himalayan glaciers melt
- Ongoing risk of hunger in several developing regions because of crop productivity declines combined with rapid population growth and urbanization

Australia and New Zealand

- Intensified water security problems in southern and eastern Australia and parts of New Zealand by 2030
- Further loss of biodiversity in ecologically rich sites by 2020
- Increased storm severity and frequency in several places

Africa

- Decreased water availability by 2020 for 75 million to 250 million people
- Loss of arable land, reduced growing seasons and reduced yields in some areas
- Decreased fish stocks in large lakes

Polar regions

- Thinning and shrinking of glaciers and ice sheets
- Changes in the extent of Arctic sea ice and permafrost
- Deeper seasonal thawing of permafrost

Small islands

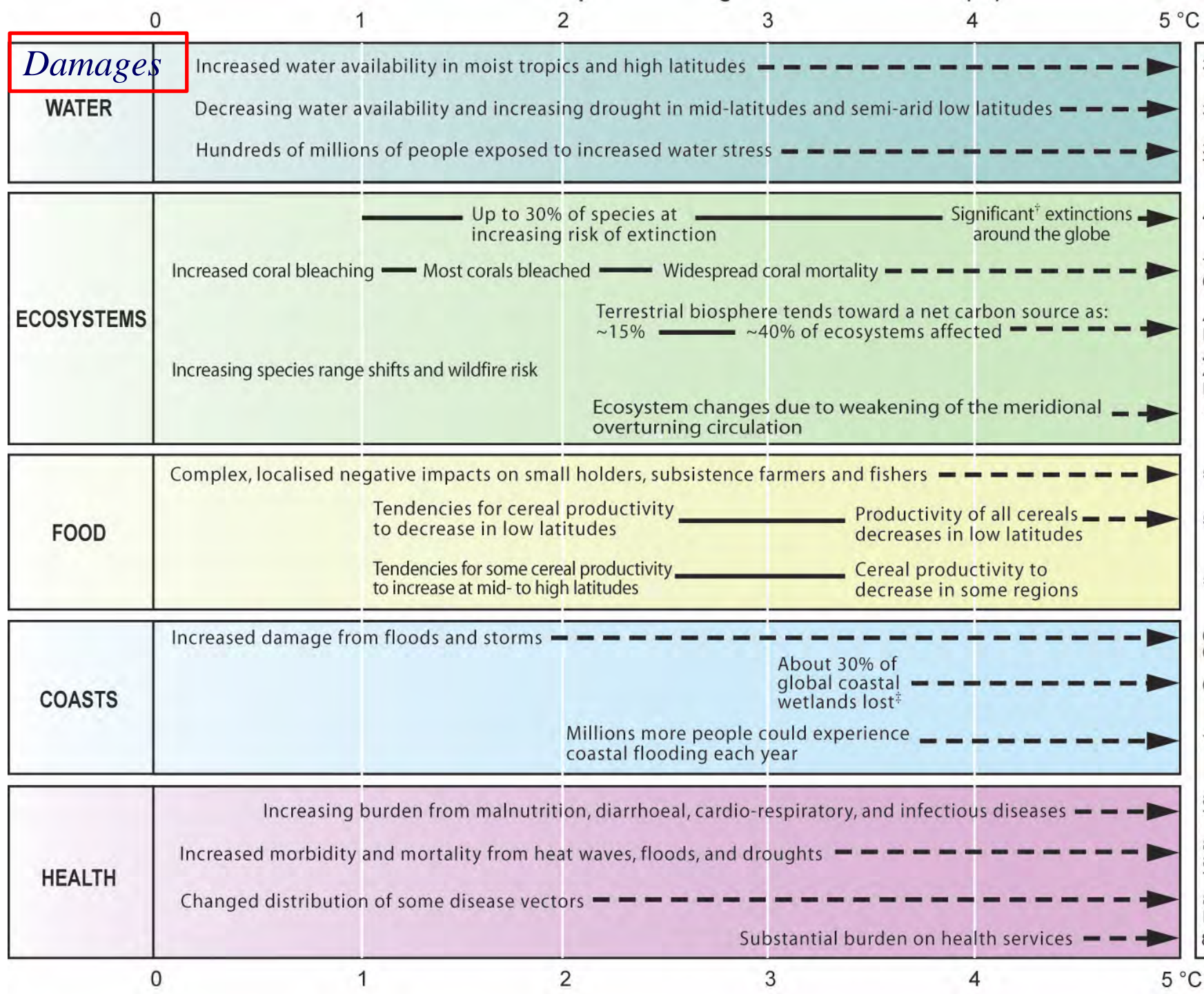
- Threats to vital infrastructure, settlements and facilities because of sea-level rise
- Reduced water resources in many places by midcentury
- Beach erosion, coral bleaching and other deteriorating coastal conditions, leading to harmed fisheries and reduced value as tourist destinations
- Invasion by nonnative species, especially on mid- and high-latitude islands

Central and South America

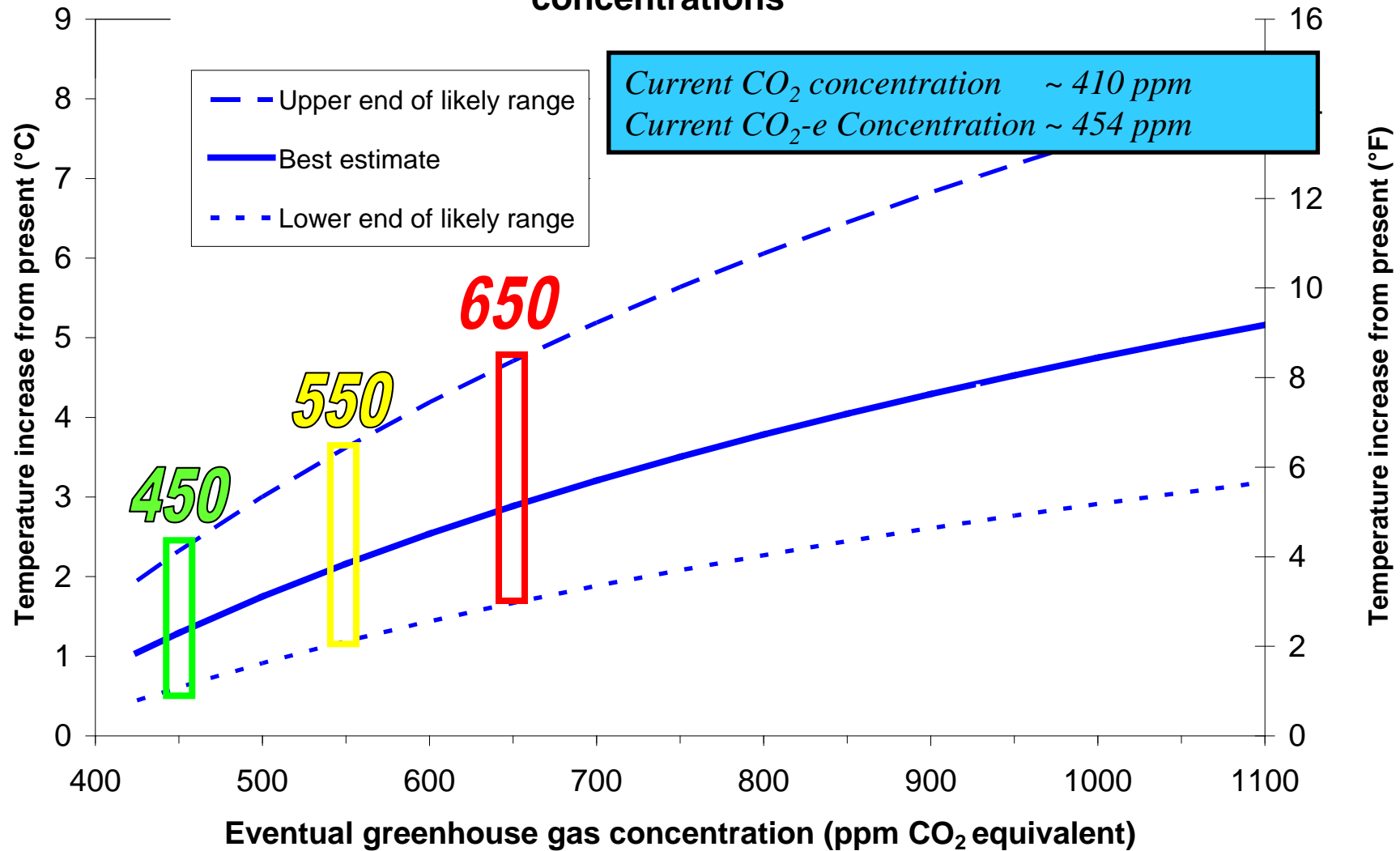
- Gradual replacement of tropical forest by savanna in eastern Amazonia
- Replacement of semiarid vegetation by arid-land vegetation
- Species extinctions in many tropical areas
- Reduced water availability
- Loss of arable land in drier areas
- Decreased yields of some important crops
- Reduced livestock productivity

- *Agriculture! (Temperature & Precipitation)*
- *Both Positives & Negatives*
- *Developing Countries:*
 - *agriculture*
 - *tropics*
 - *poor*

Source: Scientific American



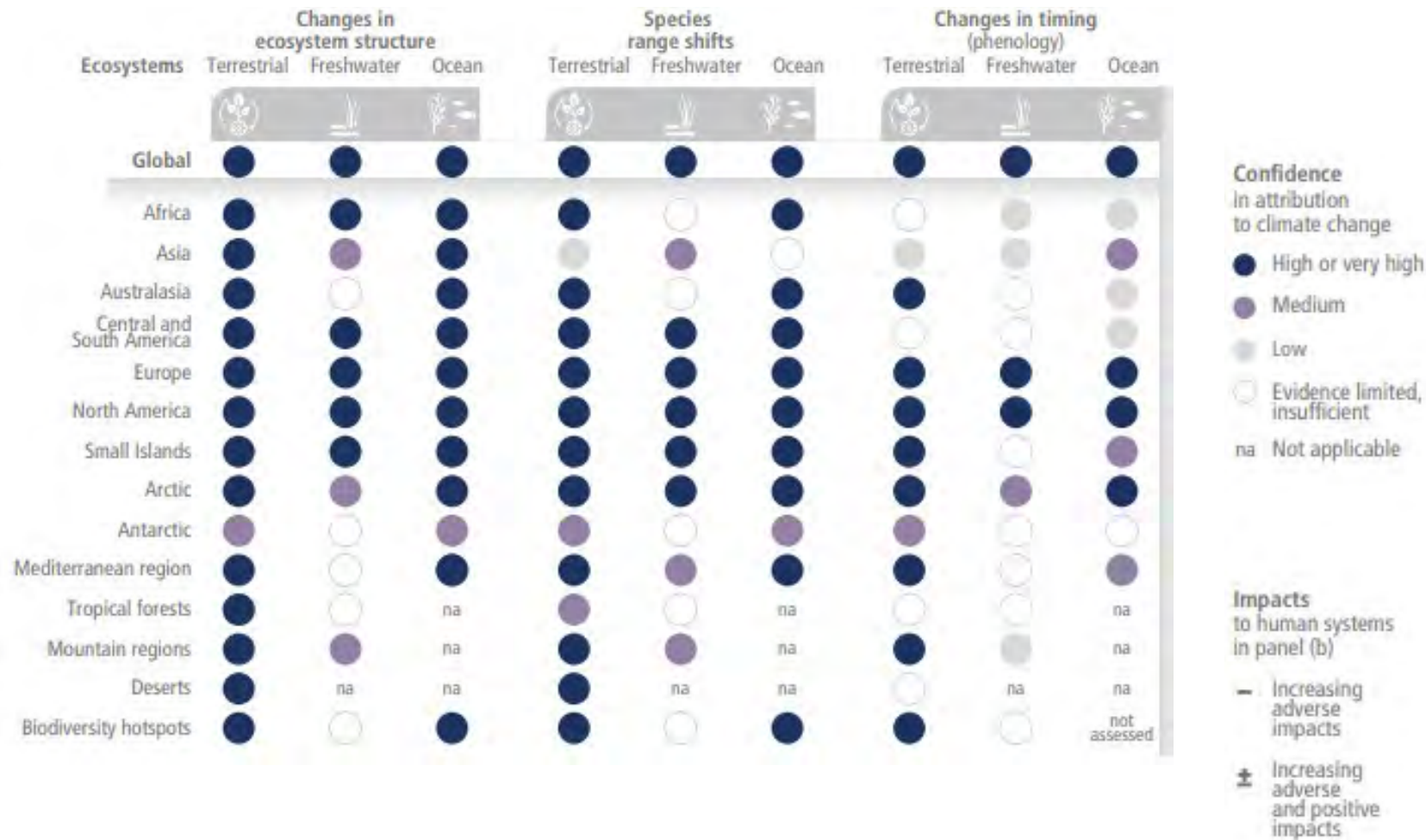
Likely global warming from stabilization at different greenhouse gas concentrations



Note: "Likely" is defined as greater than a 66% probability of occurrence. Source: IPCC Fourth Assessment Report.



Global Climate Change Impacts: Ecosystems



Global Climate Change Impacts: Human Systems



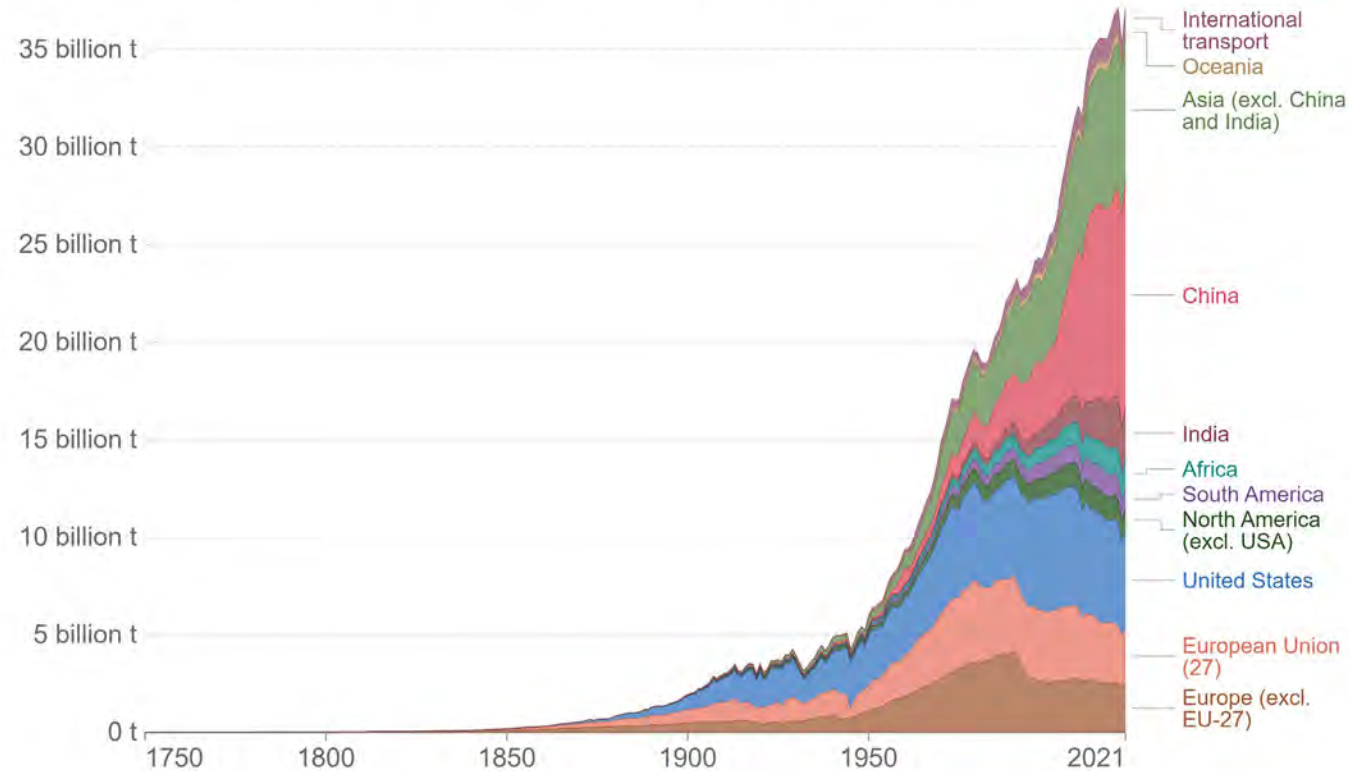
Source: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Annual CO₂ Emissions by Region

Annual CO₂ emissions by world region

This measures fossil fuel and industry emissions¹. Land use change is not included.

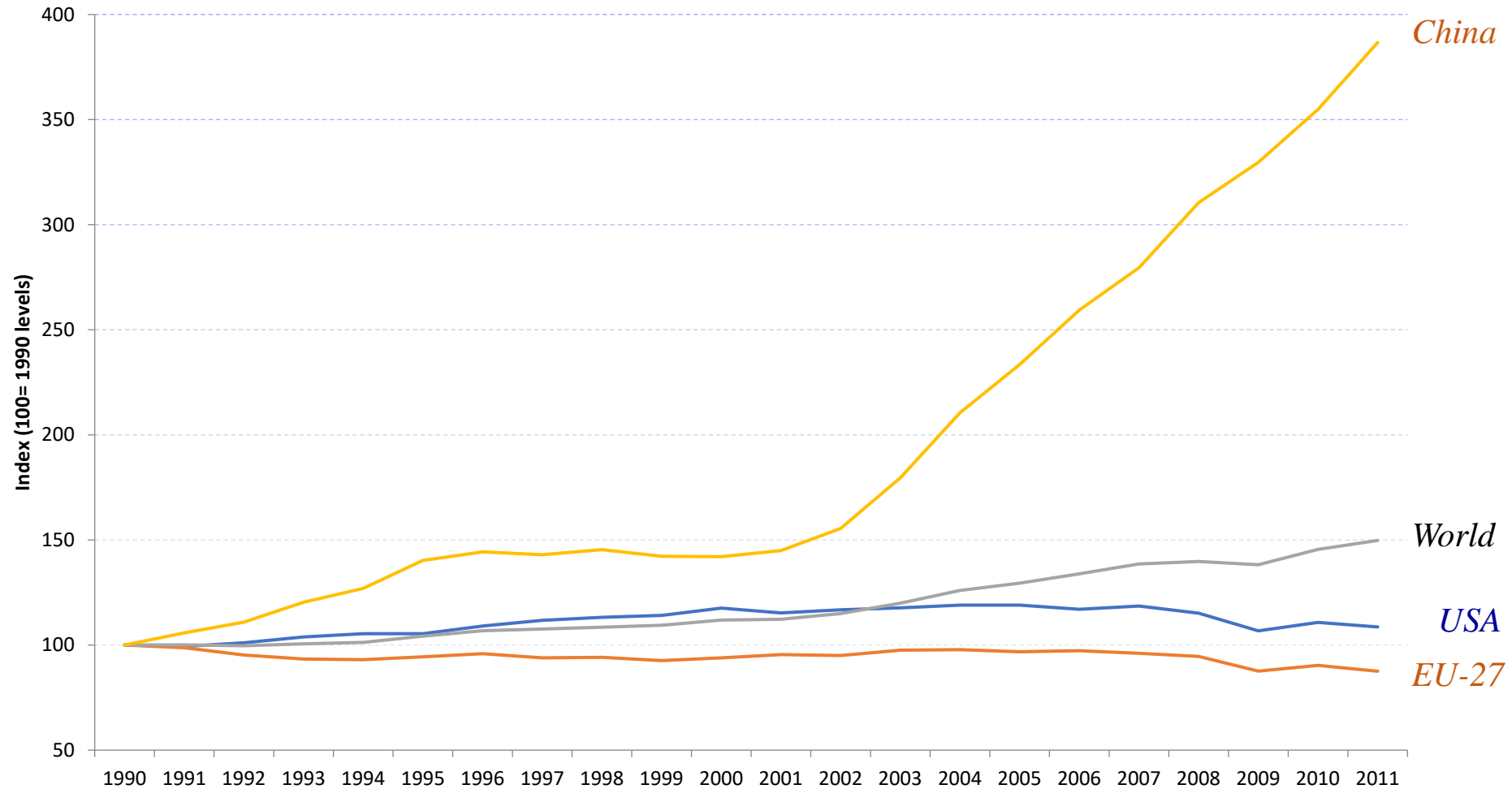
Our World
in Data



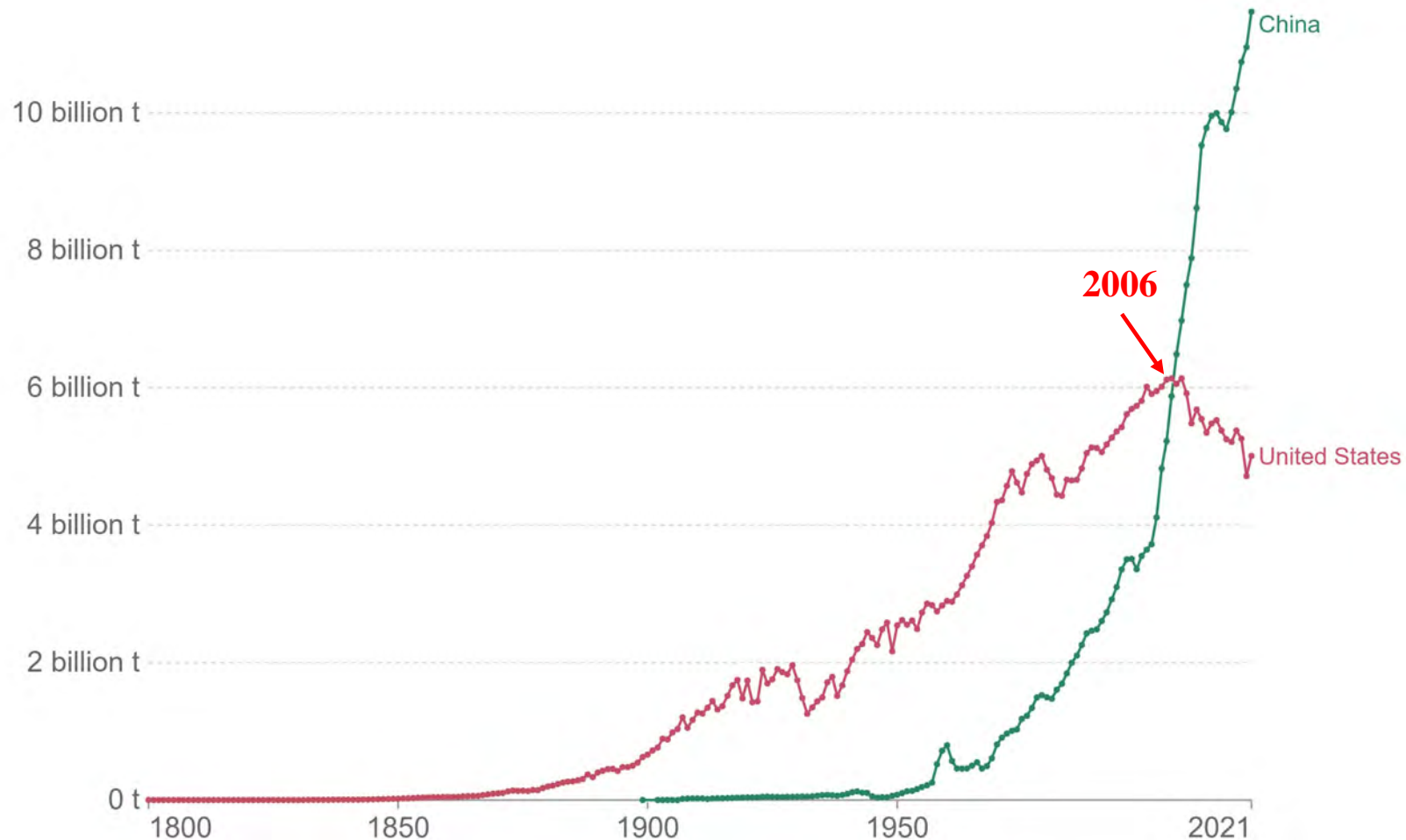
Source: Our World in Data based on the Global Carbon Project (2022) OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO₂) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO₂ includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Percentage Change in CO₂ Emissions: USA, China, EU, & World



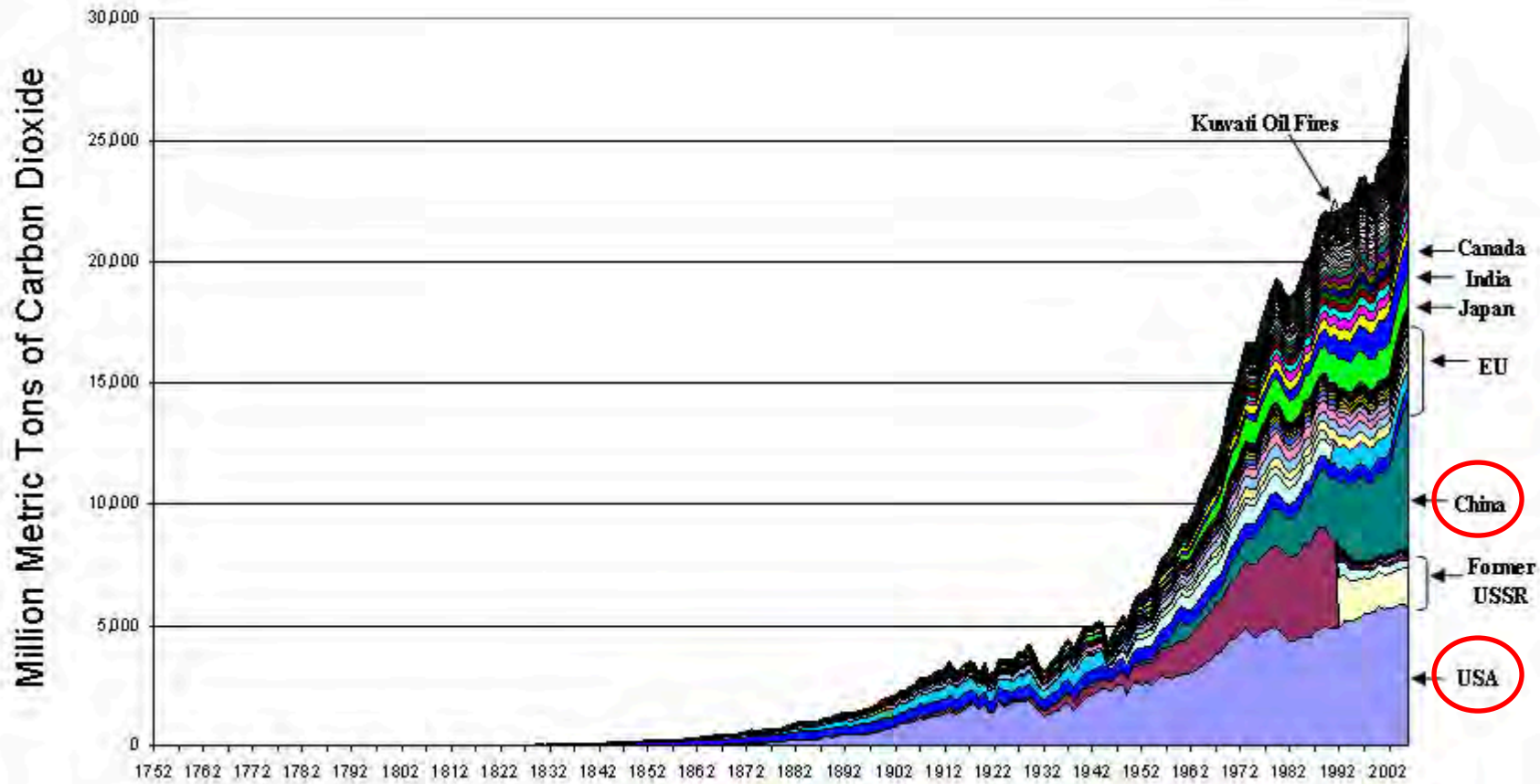
Energy-Related CO₂ Emissions, China & US, 1990-2021



Source: Our World in Data based on the Global Carbon Project (2022) OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Cumulative CO₂ Emissions, 1752-2002

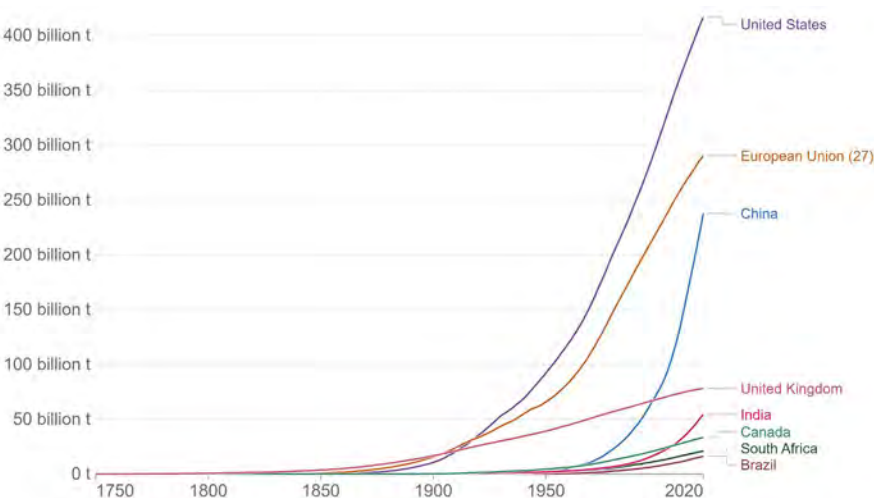
(Contributions to Atmospheric Stock → Damages)



Cumulative CO₂ Emissions

Cumulative CO₂ Emissions

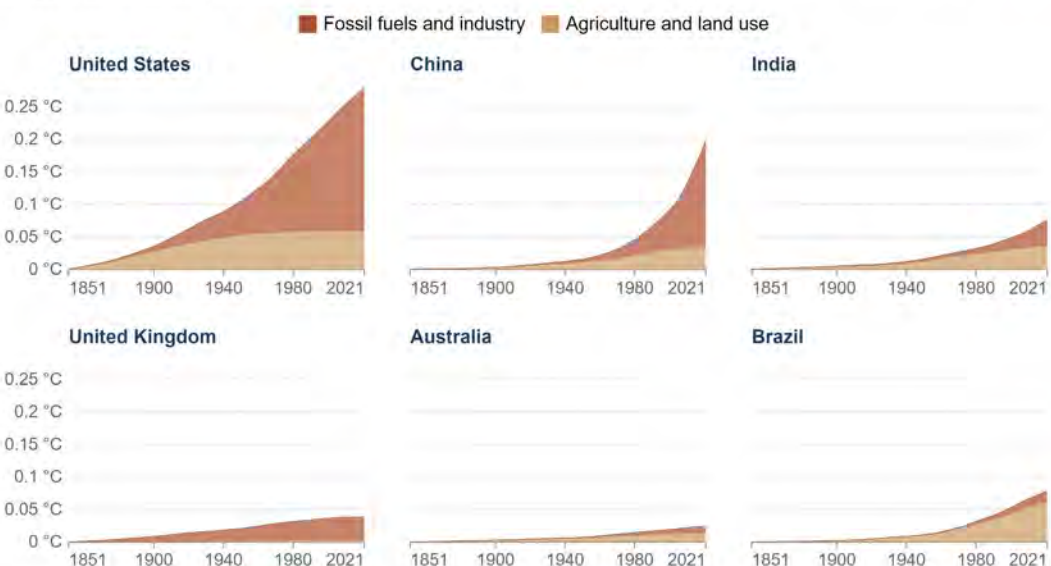
Includes fossil fuels and industry, excludes land use change



Source: Our World in Data based on the Global Carbon Project
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

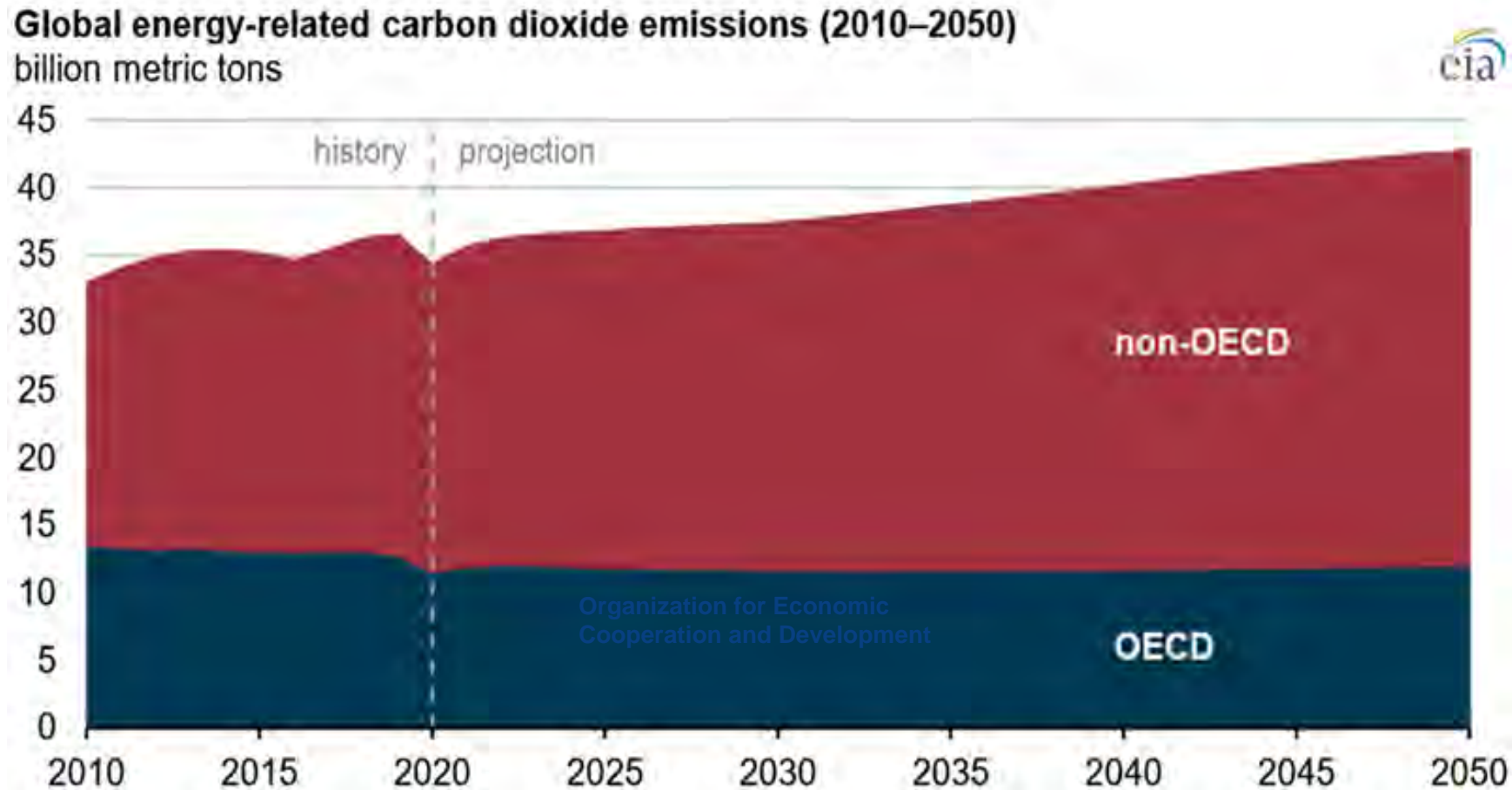
Global warming contributions from fossil fuels and land use, 1851 to 2021

The global mean surface temperature change as a result of a country or region's cumulative emissions of three gases – carbon dioxide, methane, and nitrous oxide. This does not include cooling impacts from sulphur dioxide and aerosols, so net warming can be lower.



Source: Jones et al. (2023). National contributions to climate change due to historical emissions of carbon dioxide, methane and nitrous oxide.
OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY

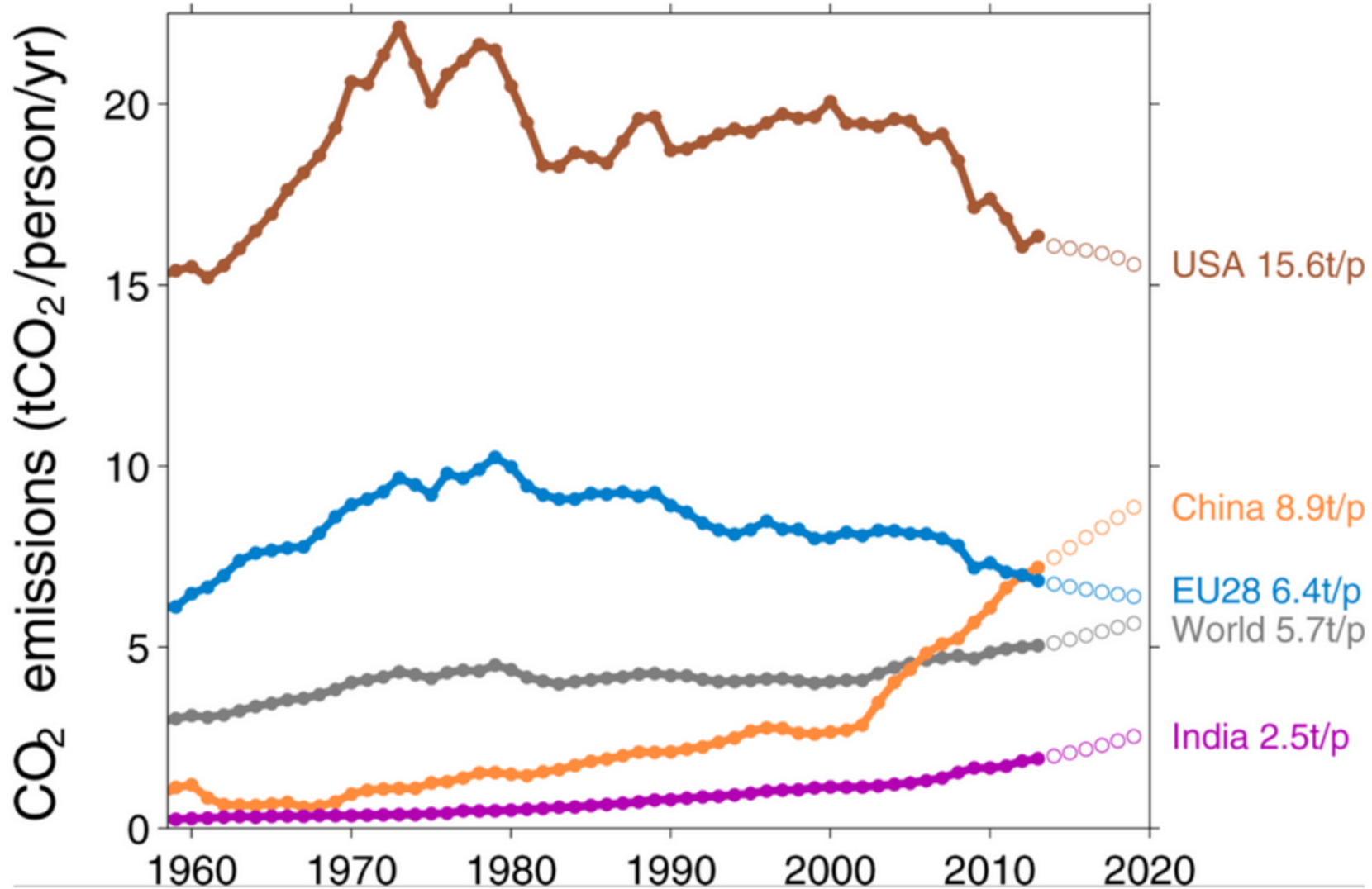
Predictions of Future Energy-Related CO₂ Emissions by Region



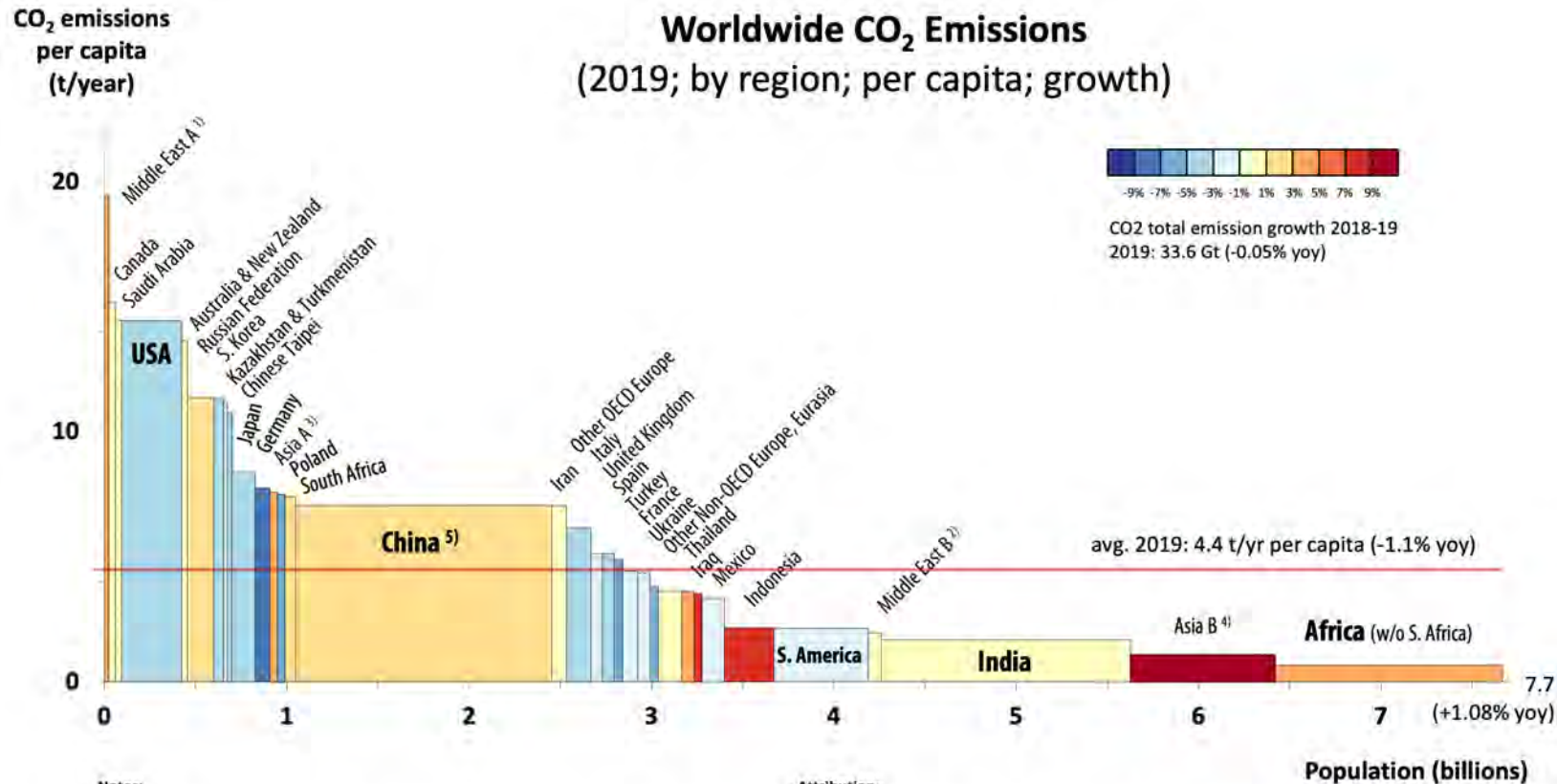
Source: U.S. Energy Information Administration, [*International Energy Outlook 2021*](#), Reference case, October 2021

Note: OECD is [Organization for Economic Cooperation and Development](#).

CO₂ Emissions per Capita Trends



CO₂ Emissions per Capita, 2019



Notes:

CO₂ emissions from fuel combustion only; no other greenhouse gases or natural sources; aviation and marine bunkers not shown as territory but included in average and totals.

¹⁾ Middle East A: Bahrain, Oman, Kuwait, Qatar, United Arab Emirates

²⁾ Middle East B: Israel, Jordan, Lebanon, Syrian Arab Republic, Yemen

³⁾ Asia A: Brunei Darussalam, Malaysia, Mongolia, Singapore

⁴⁾ Asia B: Asia without Asia A, China, India, Thailand, Chinese Taipei, Indonesia, S. Korea, Japan

⁵⁾ China: People's Rep. of China, Hong Kong

Attribution:

Based on IEA (2021), "Greenhouse gas emissions from energy", www.iea.org/statistics. All rights reserved; as modified by Thomas Schulz, AQAL Capital GmbH.
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

Version:

02-Nov-2021 by Thomas Schulz, AQAL Capital GmbH
(<https://aqalcapital.com/2019-worldwide-co2-emissions>)

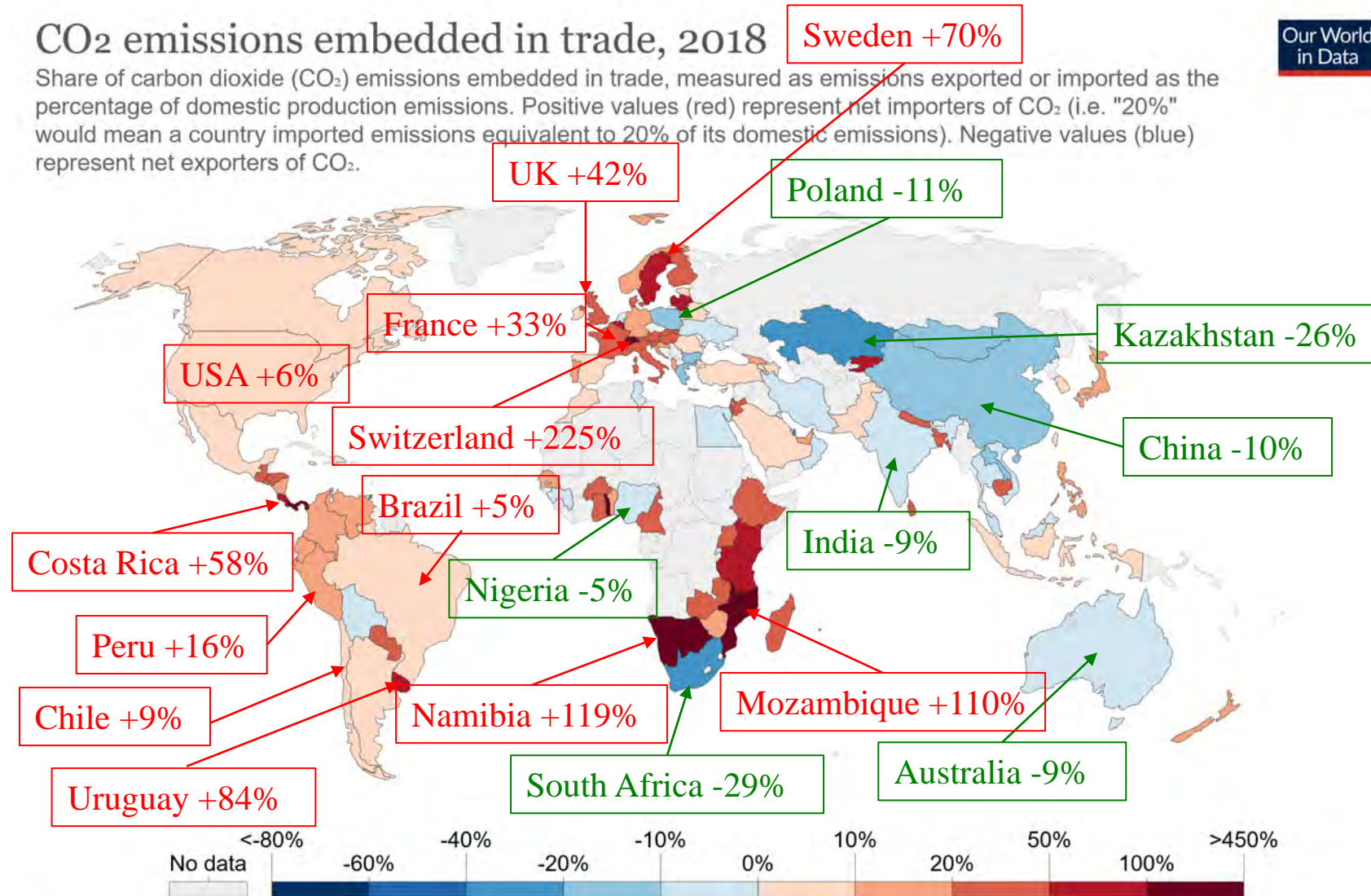


What About Consumption-Based Emissions Accounting?

CO₂ emissions embedded in trade, 2018

Share of carbon dioxide (CO₂) emissions embedded in trade, measured as emissions exported or imported as the percentage of domestic production emissions. Positive values (red) represent net importers of CO₂ (i.e. "20%" would mean a country imported emissions equivalent to 20% of its domestic emissions). Negative values (blue) represent net exporters of CO₂.

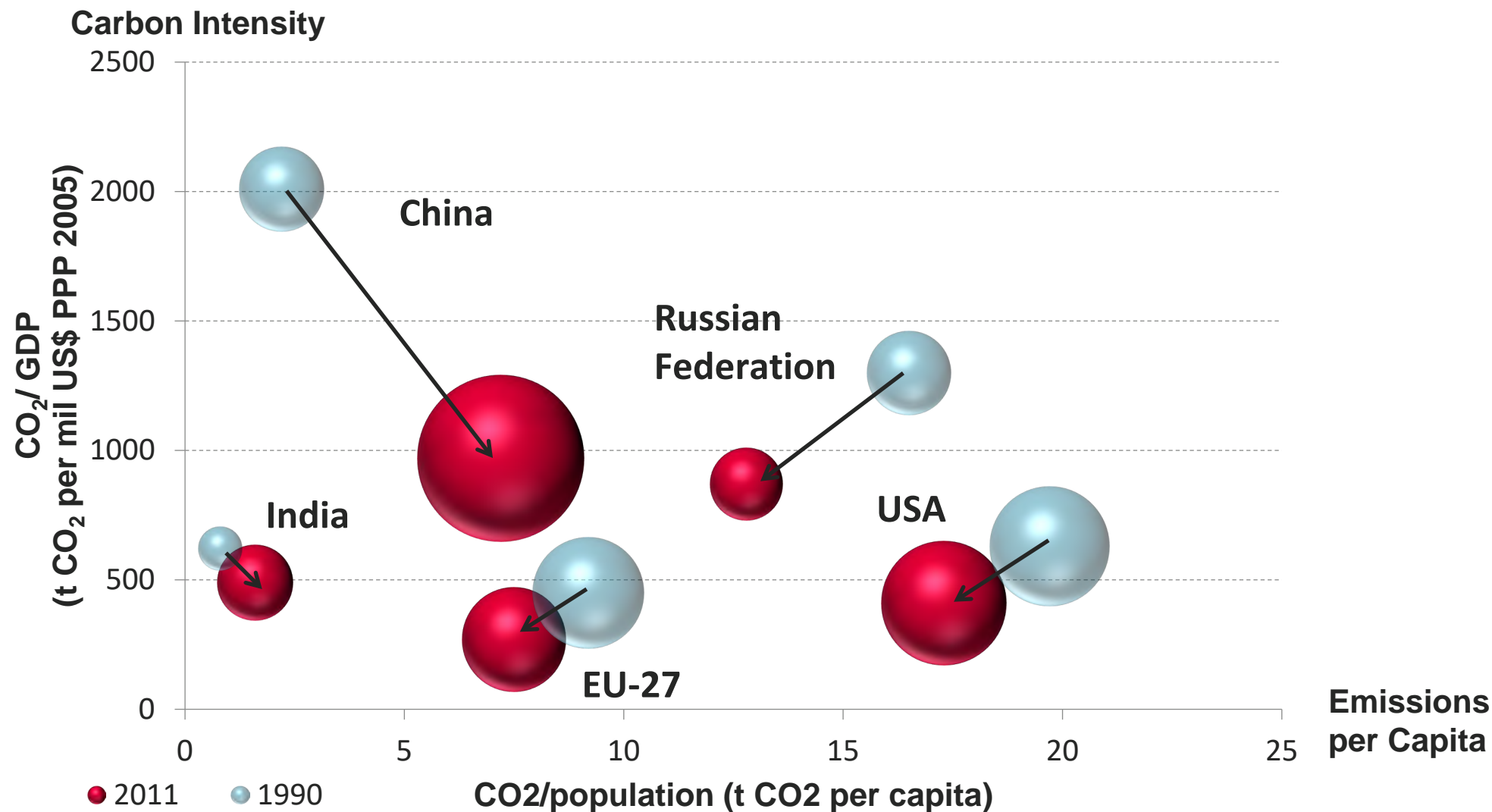
Our World
in Data



Source: Peters et al. (2012 updated); Global Carbon Project

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

CO₂ Emission Intensity and Per Capita Trends for Top Five Emitters



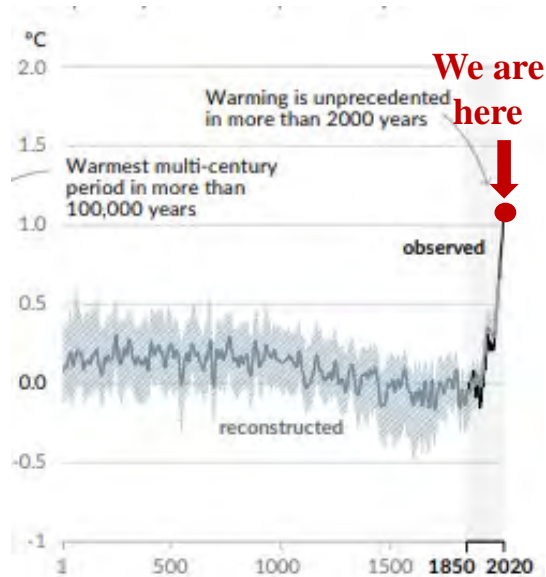
Size of circle represents CO₂ emissions in given year.

Options to Address Global Climate Change

- **Reduce Net Emissions of CO₂ (& Other Greenhouse Gases – GHGs)**
 - Switch fuels: coal, petroleum, natural gas, nuclear, renewables
 - Change industrial production processes (example: cement production)
 - Carbon capture & storage (CCS) at point of electricity generation
 - Reduce energy demand
 - Increase efficiency of energy generation
 - Reduce rate of deforestation
 - Increase “natural” CO₂ removal through land-use changes (afforestation)
- **Geoengineering**
 - CO₂ removal (direct air capture, ocean fertilization, etc.)
 - Solar radiation management (deflect sunlight or increase reflectivity)
- **Adaptation**

Meaningful reduction of climate change risk may require progress towards “Net Zero” by mid-century

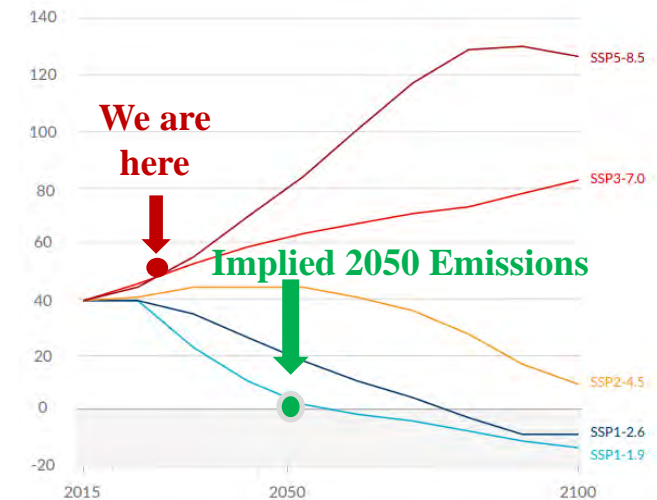
Change
in Global Surface Temperature



Potential Future
Global Temperature



Carbon Dioxide Emissions
(GtCO₂/year)



Source: IPCC, 2021: Summary for Policymakers. In: “Climate Change 2021, The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Plan on Climate Change” From Box SPM.1.1 and Figure SPM.8.

Key Take-Aways

1. Climate change is a *global commons problem*.
2. Climate change is linked with atmospheric *stock* of accumulated emissions.
3. *Sources* of CO₂ & other GHG emissions are diverse.
4. *Damages* of climate change are diverse, but worst in *poor countries*.
5. *Key approaches* to addressing climate change: reduce net emissions; geoengineering; and adaptation.
6. *Emissions flat to declining* in most OECD countries.
7. *Emissions increasing* in large emerging economies.
8. *Great differences* among countries in per capita emissions.
9. *Great differences* among countries in emissions intensity (CO₂/GDP)