



Oct 29: Carbon Sequestration and Climate Change

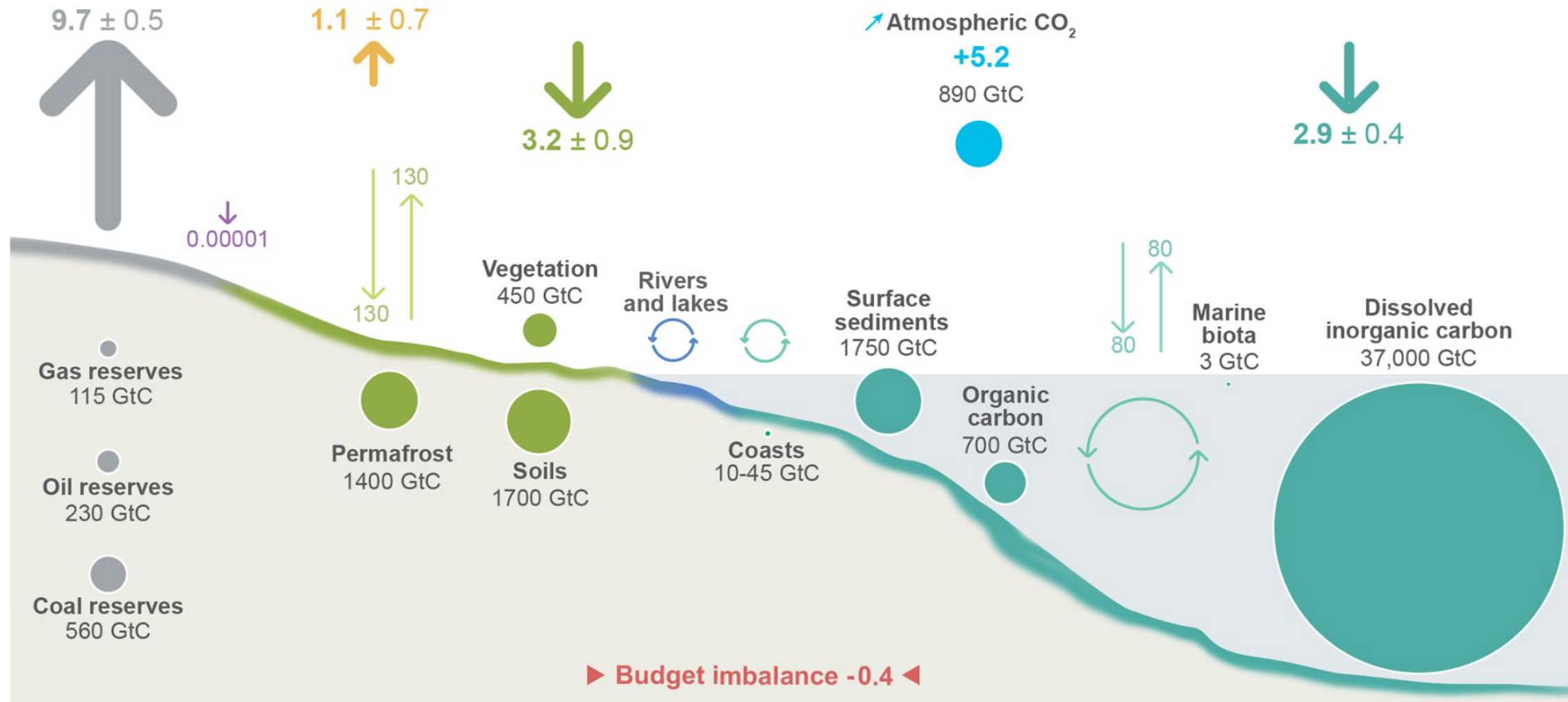
Foci of the Day

- Carbon sequestration, credit, and market
- Carbon footprint

Reading

- 1) Global carbon budget: <https://carbonmonitor.org/>
- 2) World population: <https://www.worldometers.info/world-population/>
- 3) Primary energy consumption per capita (<https://ourworldindata.org/grapher/per-capita-energy-use>)
- 4) State and trends of carbon pricing dashboard:
https://carbonpricingdashboard.worldbank.org/?utm_source=chatgpt.com

The global carbon cycle



**Anthropogenic fluxes
2014-2023 average
GtC per year**

↑ Fossil CO₂ E_{FOS}
 ↑ Land-use change E_{LUC}
 ↓ CDR not included in E_{LUC}

↓ Land uptake S_{LAND}
 ↓ Ocean uptake S_{OCEAN}
 + Atmospheric increase G_{ATM}

▶ Budget imbalance B_{IM}
 ● Stocks GtC
 ↓↑ Natural carbon fluxes in GtC

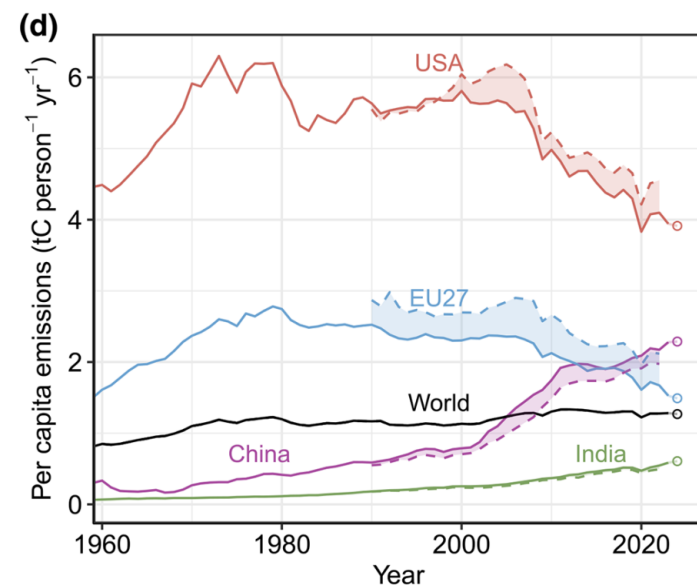
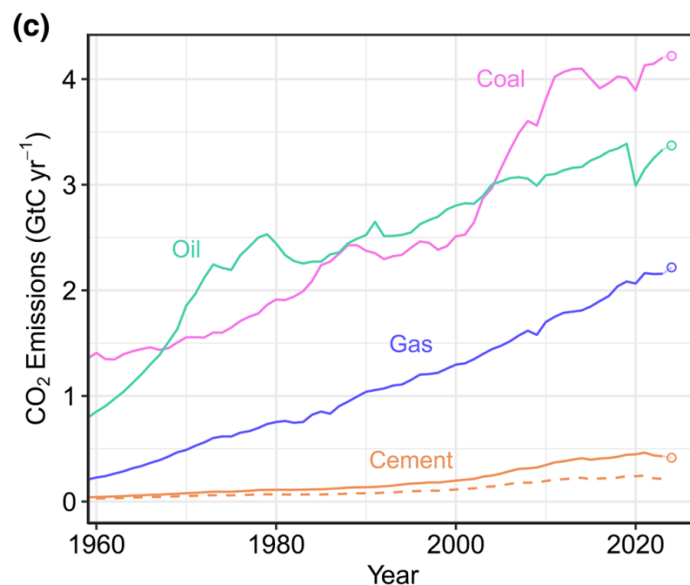
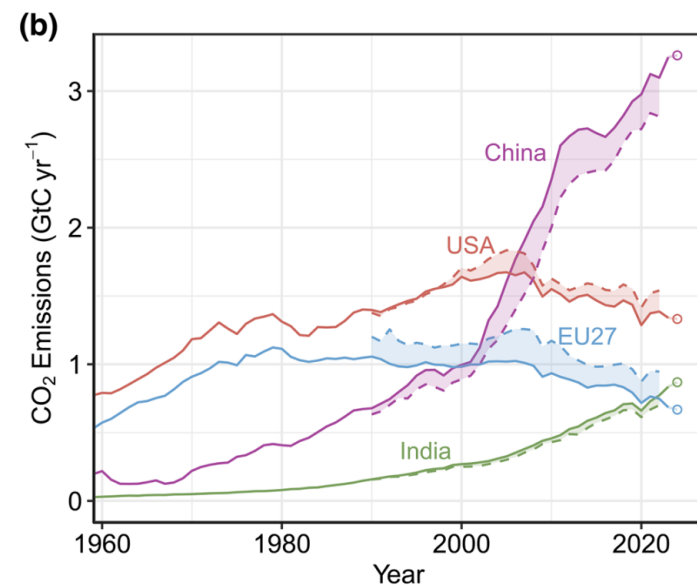
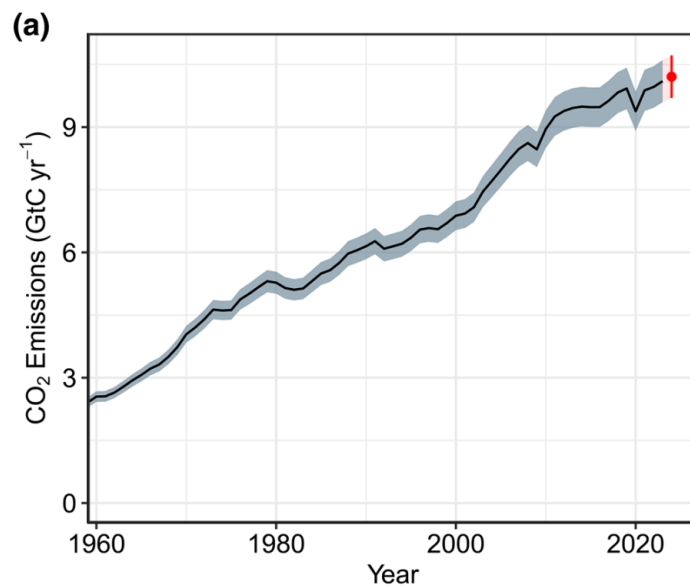


Global Carbon Budget

(<https://carbonmonitor.org/>)

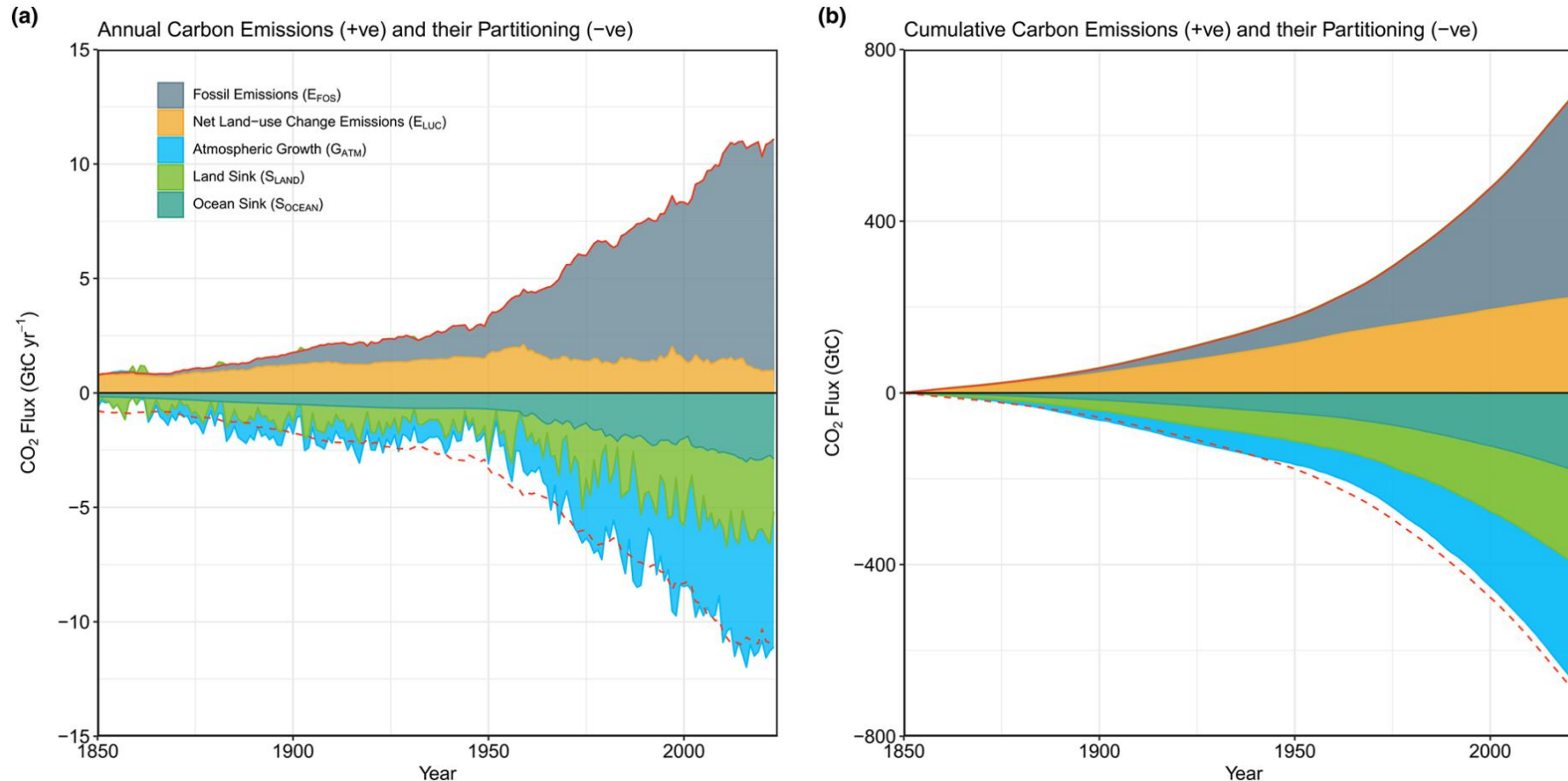
Fossil CO₂ emissions

- Different industries
- Major political entities
- Per capita
- Political debates (Paris Agreement)



Global Carbon Budget

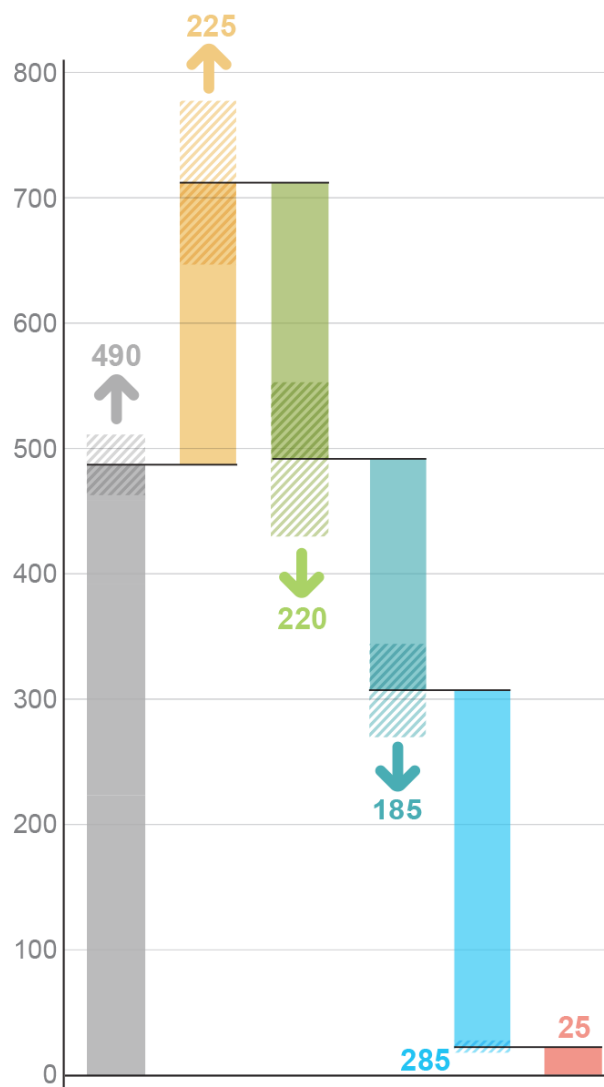
Combined components of the global carbon budget as a function of time, for fossil CO₂ emissions (EFOS, grey) and emissions from land-use change (ELUC; yellow-brown), as well as their partitioning into the atmosphere (G_{ATM}; cyan), ocean (SOCEAN; turquoise), and land (SLAND; green).



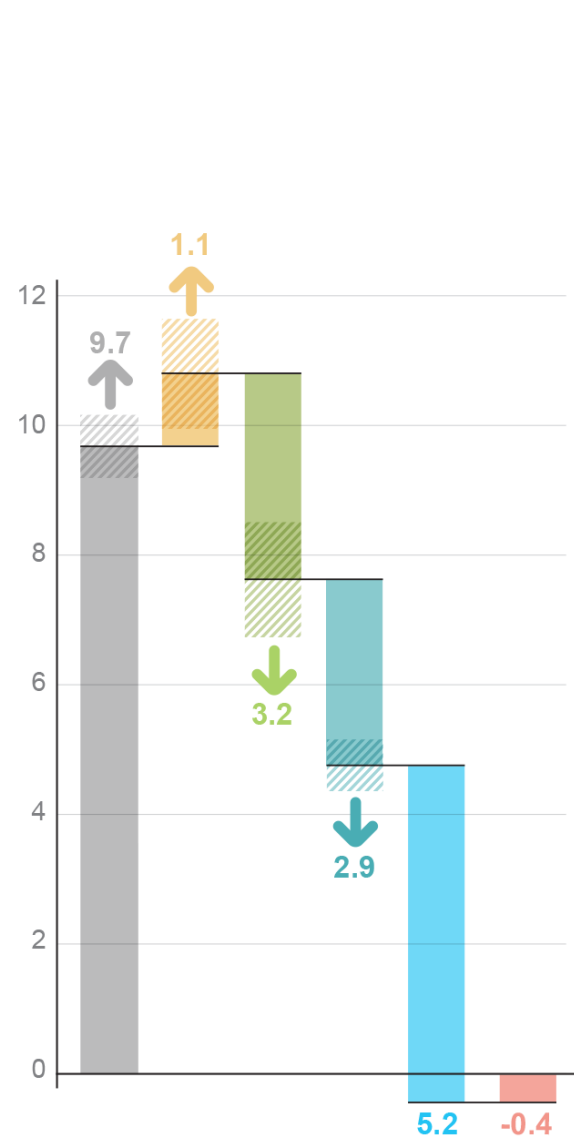


Anthropogenic carbon flows

(a) Cumulative changes 1850-2023 GtC



(b) Mean fluxes 2014-2023 GtC per year



↑ Fossil CO₂ E_{FOS}

↑ Land-use change E_{LUC}

↓ Land uptake S_{LAND}

↓ Ocean uptake S_{OCEAN}

+ Atmospheric increase G_{ATM}

░ Uncertainty values

■ Budget Imbalance B_{IM}



Reducing Carbon Emissions for Climate Warming

- 1) Carbon Footprint and Energy Use
- 2) Carbon Sequestration
- 3) Carbon Credit & Stock: Policy Perspective

1. Carbon Footprint & Energy Use

Transportation

5000 miles per year; 25 miles per gallon;
19.6 lbs. CO₂ per gallon of regular gasoline



200 gallons of regular gasoline



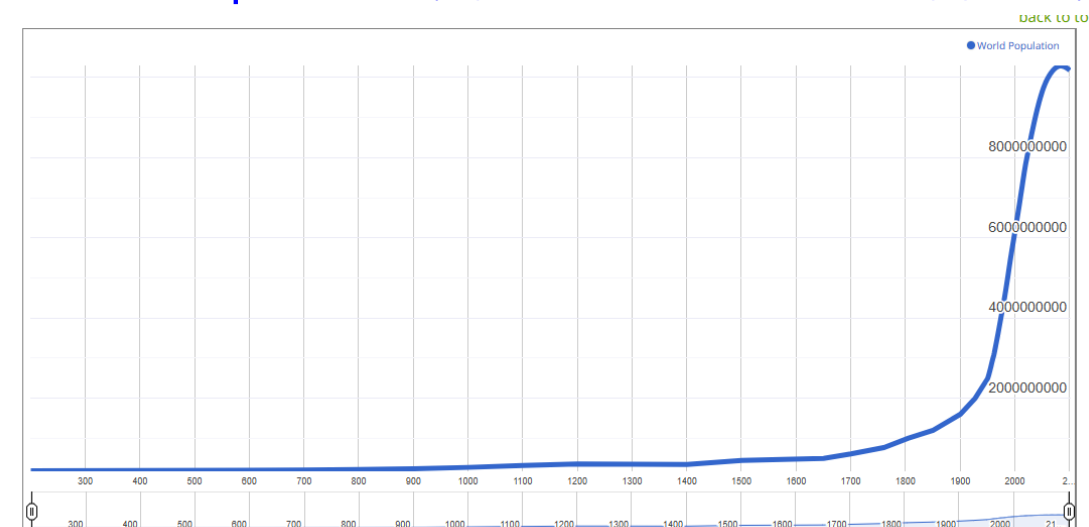
3,920 lb. CO₂ = 1069 lb. carbon (**0.485** ton
C) = **~0.97 ton** dry biomass



This class of 20 students = 19.4 ton
biomass

- A 24" diameter red Oak = 2.2 ton (dry biomass)
- Each driver need a large tree to support
- This class needs to cut down **20 large oak trees**
- MSU has 5000 students and 20,000 employees, which needs ~70,000 trees
- This is equivalent to **700 ha (>1,764 acres)**

World Population (<https://www.worldometers.info/world-population/>)



Carbon Footprint & Energy Use

Primary energy consumption per capita (<https://ourworldindata.org/grapher/per-capita-energy-use>)

Energy use per person, 2024

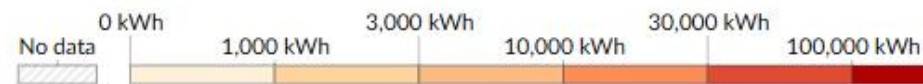
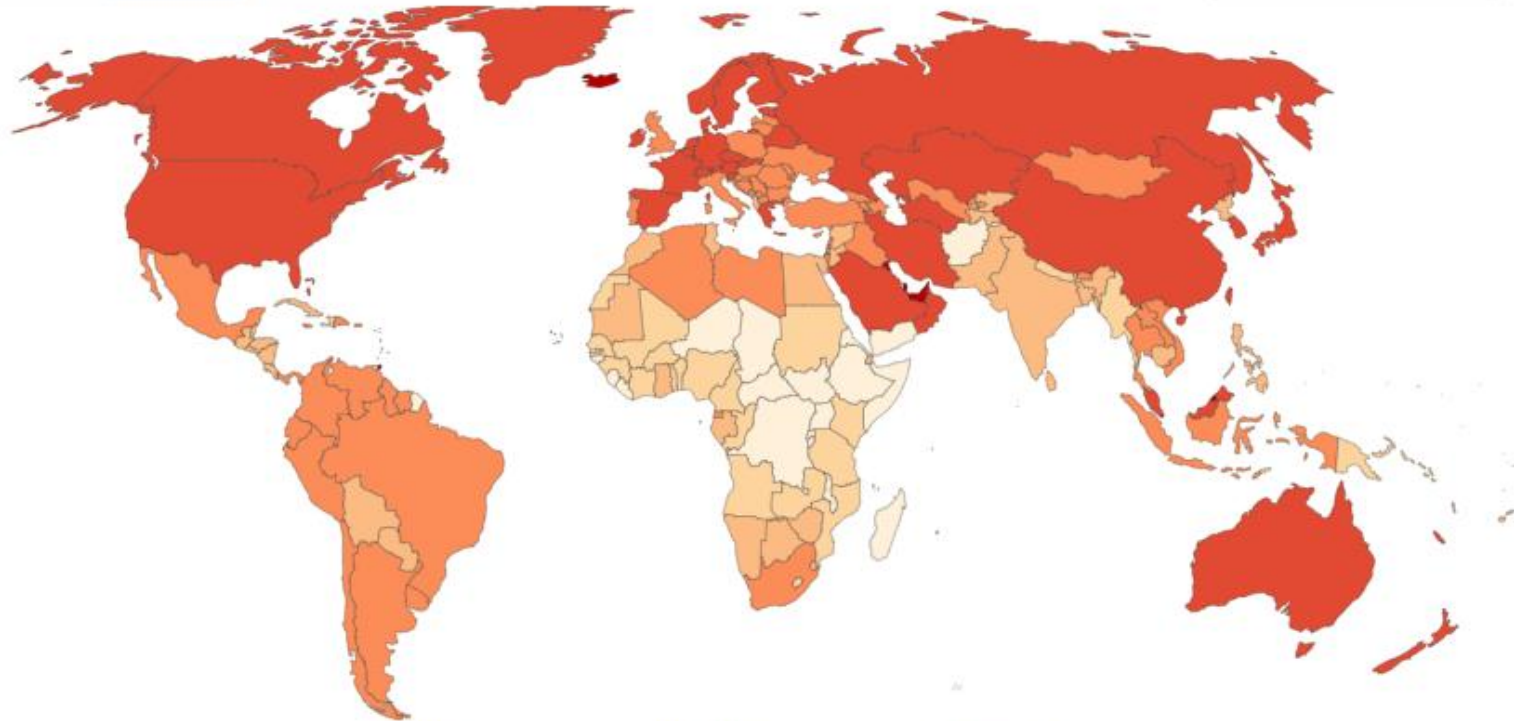
Measured in kilowatt-hours per person. Here, energy refers to primary energy using the substitution method.

Our World
in Data

Table Map Line Bar

Zoom to...

2D 3D



Play time-lapse

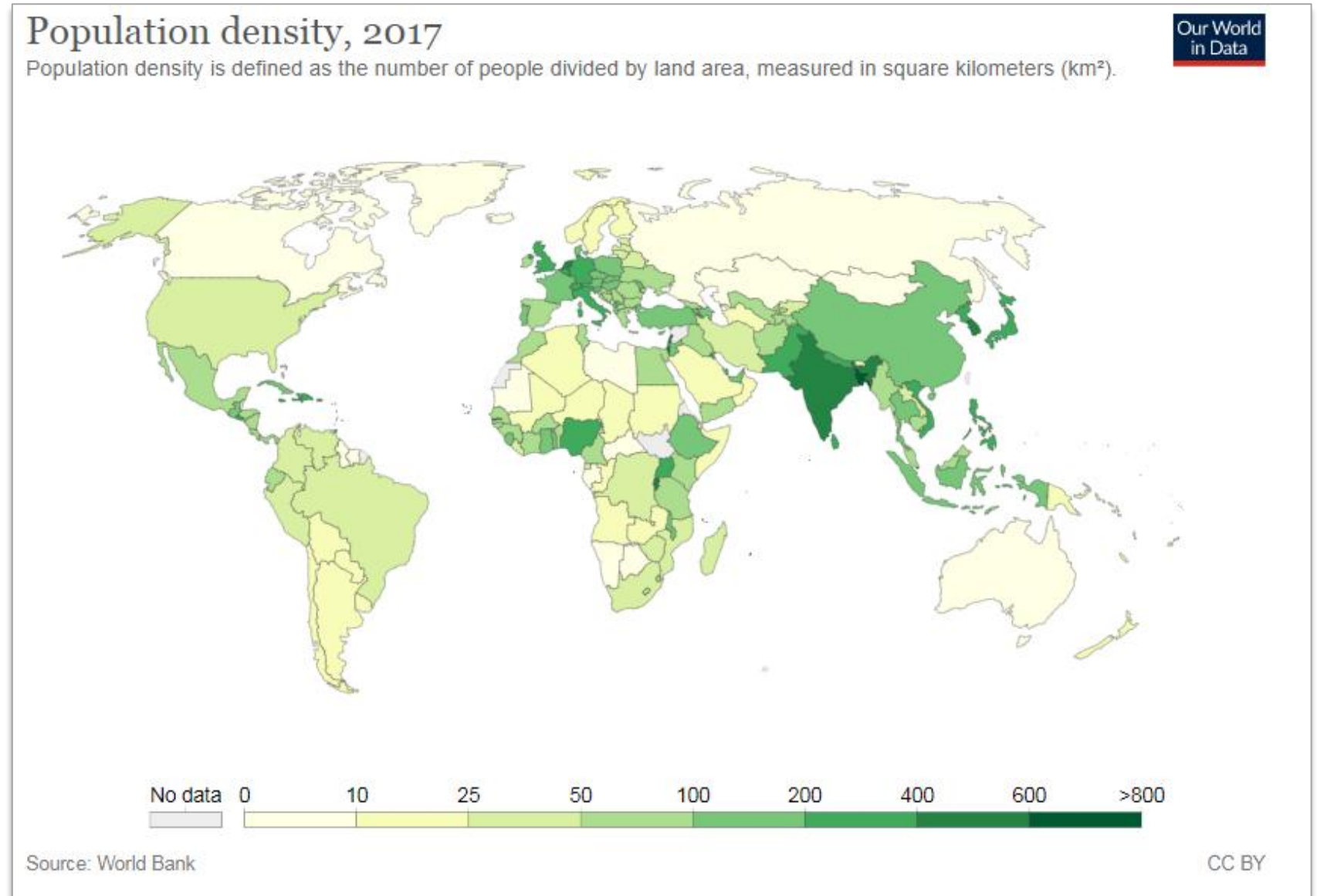
1965

2024

Data source: U.S. Energy Information Administration (2025); Energy Institute - Statistical Review of World Energy (2025); Population based on various sources (2024) - [Learn more about this data](#)

Complex Interconnections: Global Population – uneven distribution

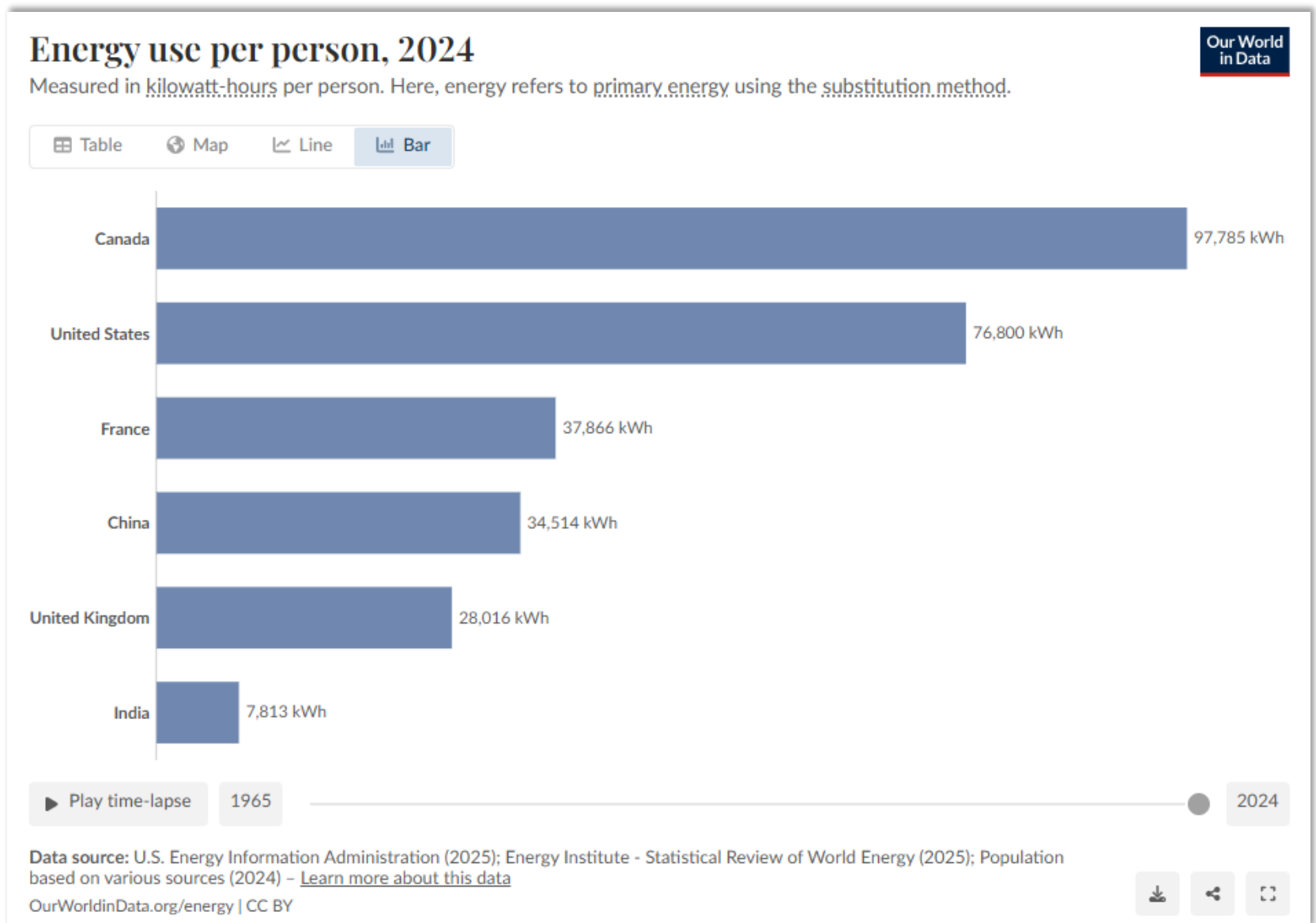
People in developing countries wants the same living standards of Americans!





Carbon Footprint & Energy Use

Primary energy consumption per capita (<https://ourworldindata.org/grapher/per-capita-energy-use>)





2. Carbon Sequestration

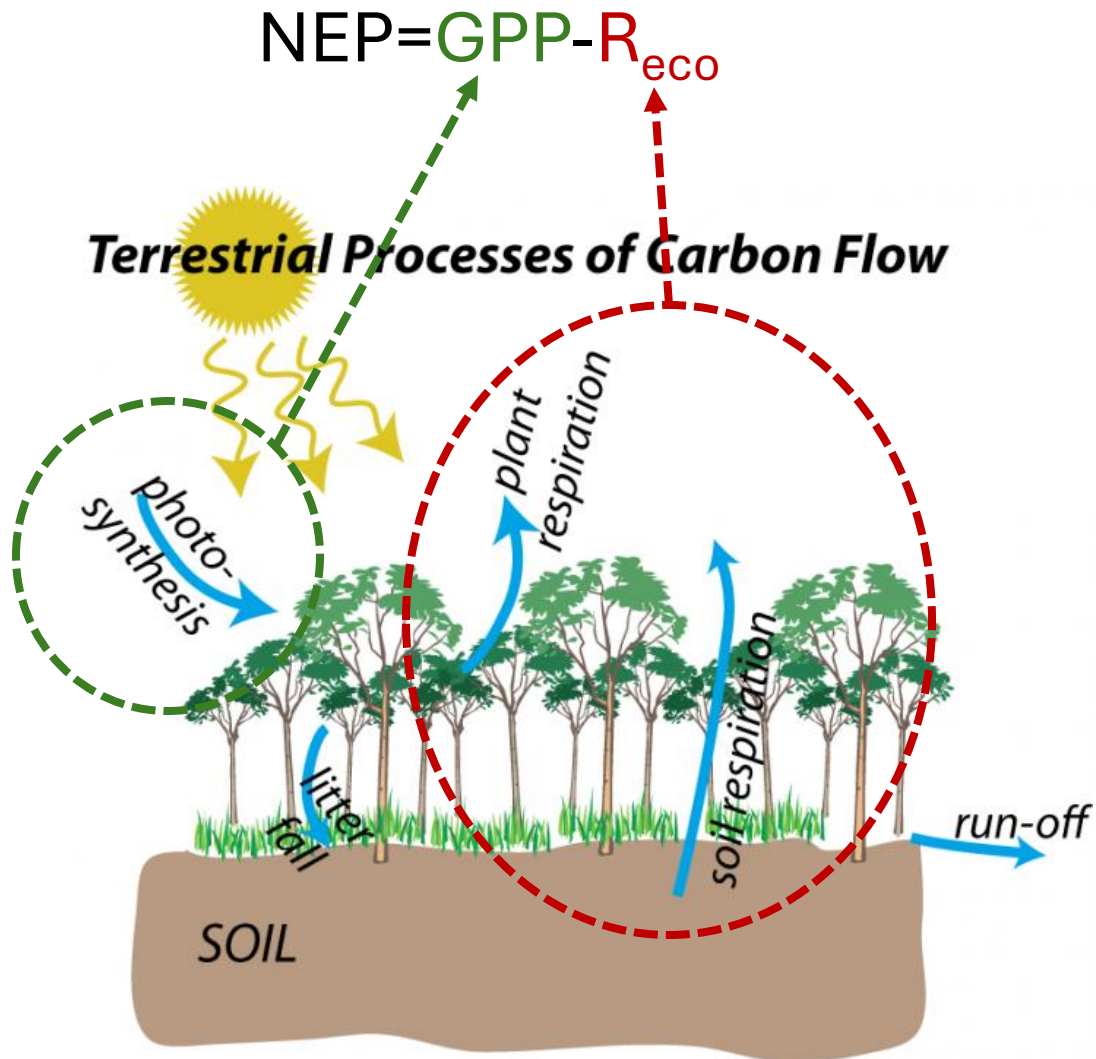
1. Natural C Sequestration

- Vegetation and Soils: Forests, grasslands, wetlands
- Oceans: Phytoplankton
- Bioenergy with Carbon Capture and Storage (BECCS)
- Others?

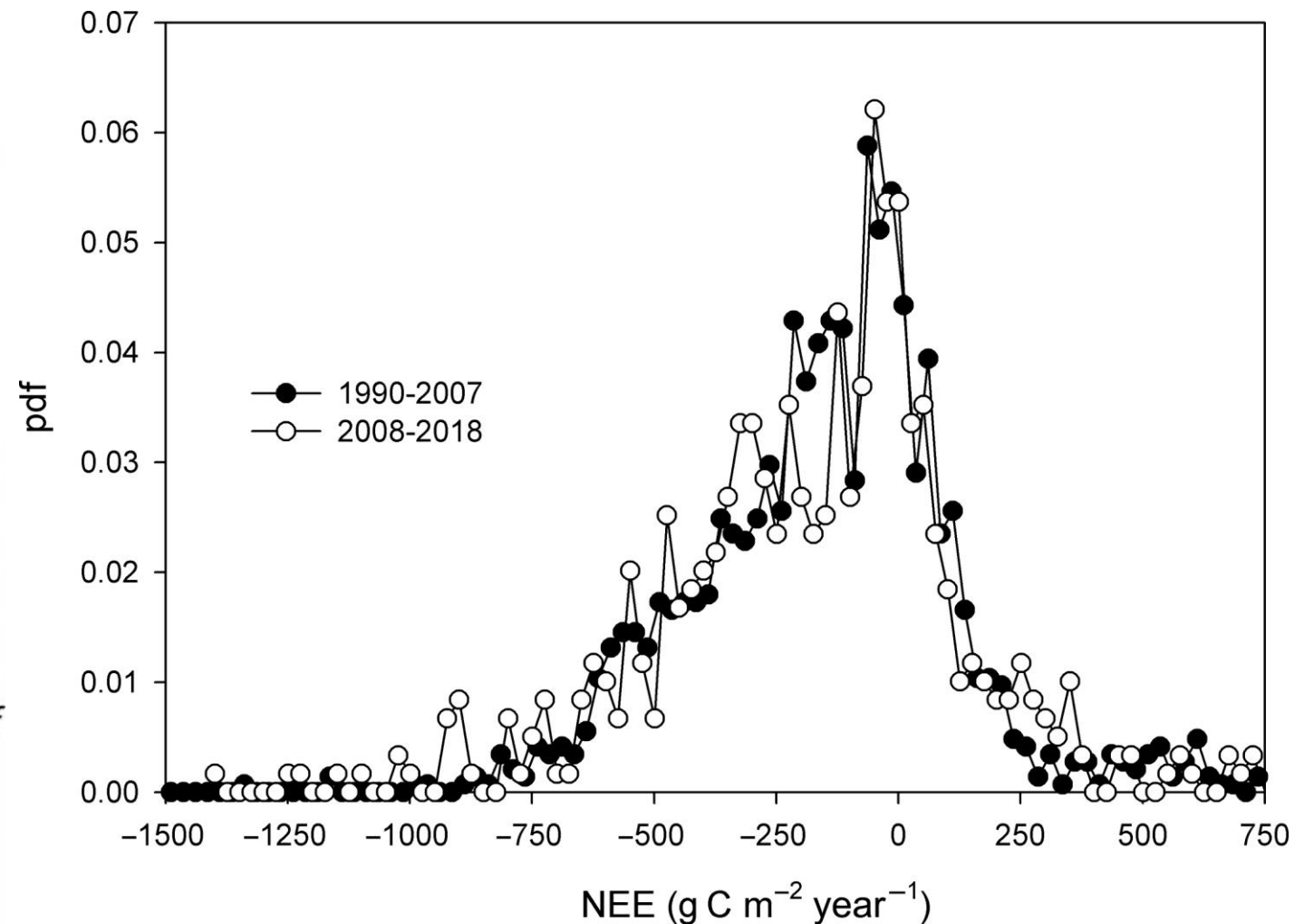
2. Artificial/Engineered C Sequestration

- Carbon Capture and Storage (CCS):
- Bioenergy with Carbon Capture and Storage (BECCS):
- Direct Air Capture (DAC):
- Others?

The Power of Terrestrial Ecosystem in C Sequestration

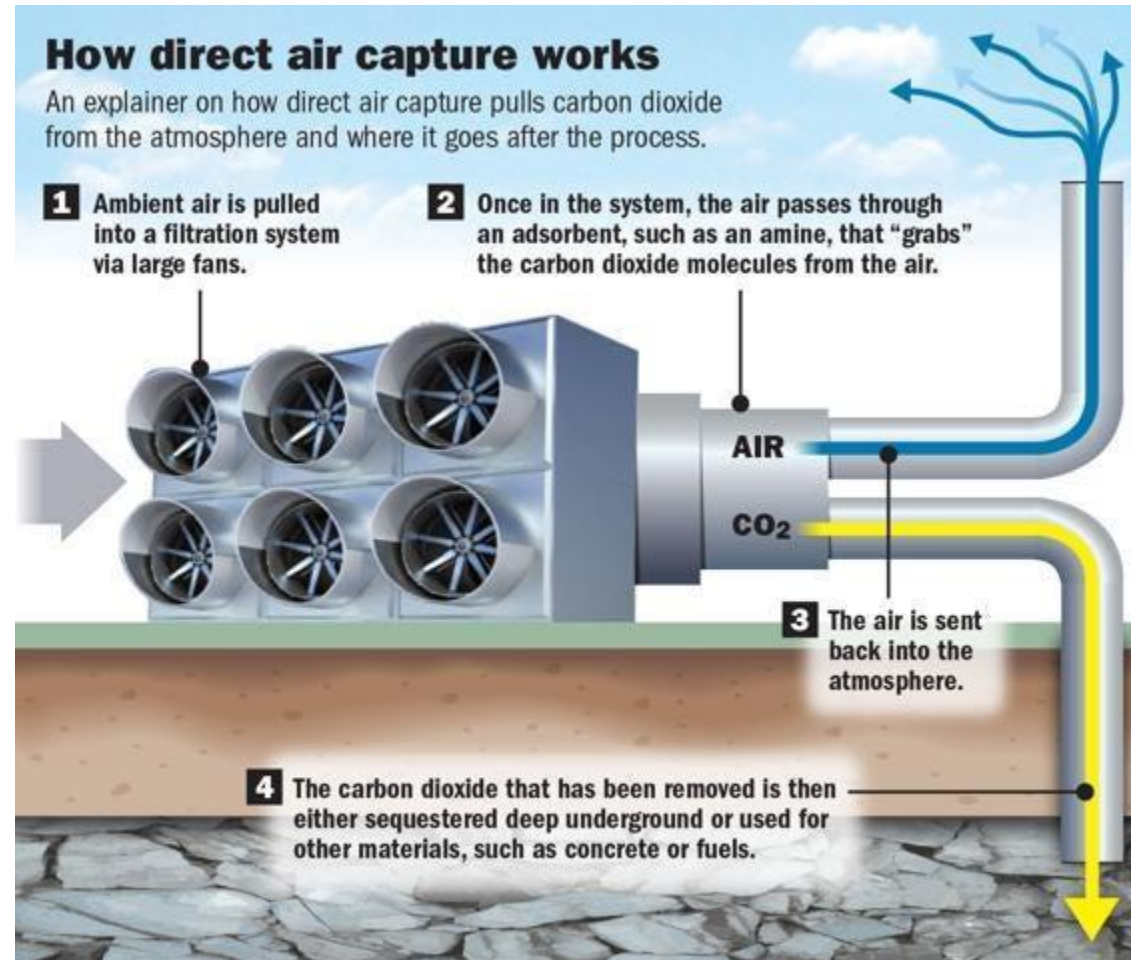


Probability density function (pdf) of annual sums of net primary production (NEP) before and after 2008 (Baldocchi 2020)



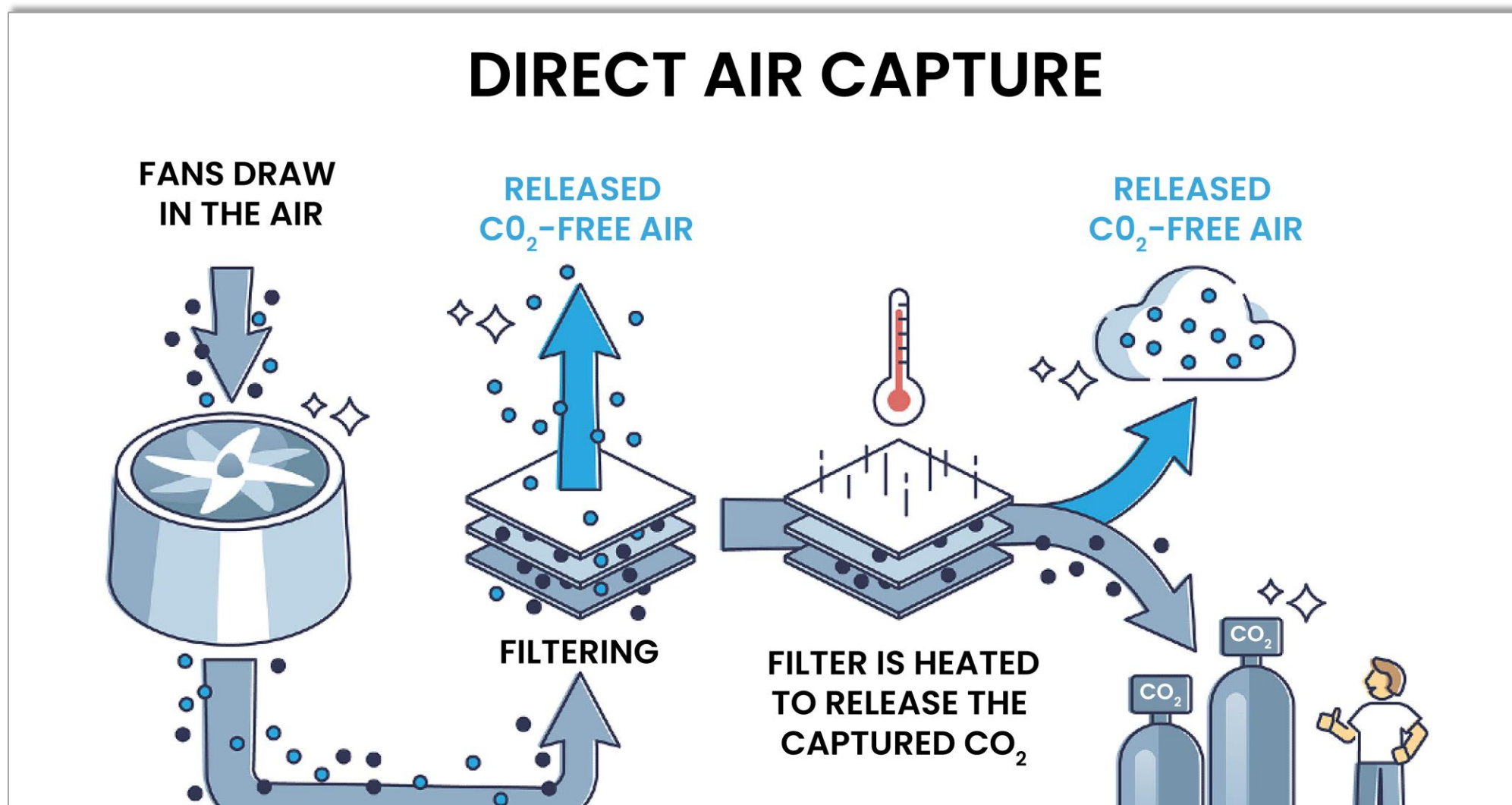
2. Artificial/Engineered C Sequestration

Direct Air Capture (<https://www.energy.gov/science/doe-explainsdirect-air-capture>): The separated CO₂ can then be permanently stored deep underground, or it can be converted into products.



World's largest Direct Air Capture and Storage (DAC+S) plant, Mammoth, starts operation in Iceland

(<https://visionias.in/current-affairs/news-today/2024-05-10/environment/worlds-largest-direct-air-capture-and-storage-dacs-plant-mammoth-starts-operation-in-iceland>)





2. Artificial/Engineered C Sequestration

Renewable energy instead of fissile fuels (Wind, solar, thermal, etc.)





2. Artificial/Engineered C Sequestration

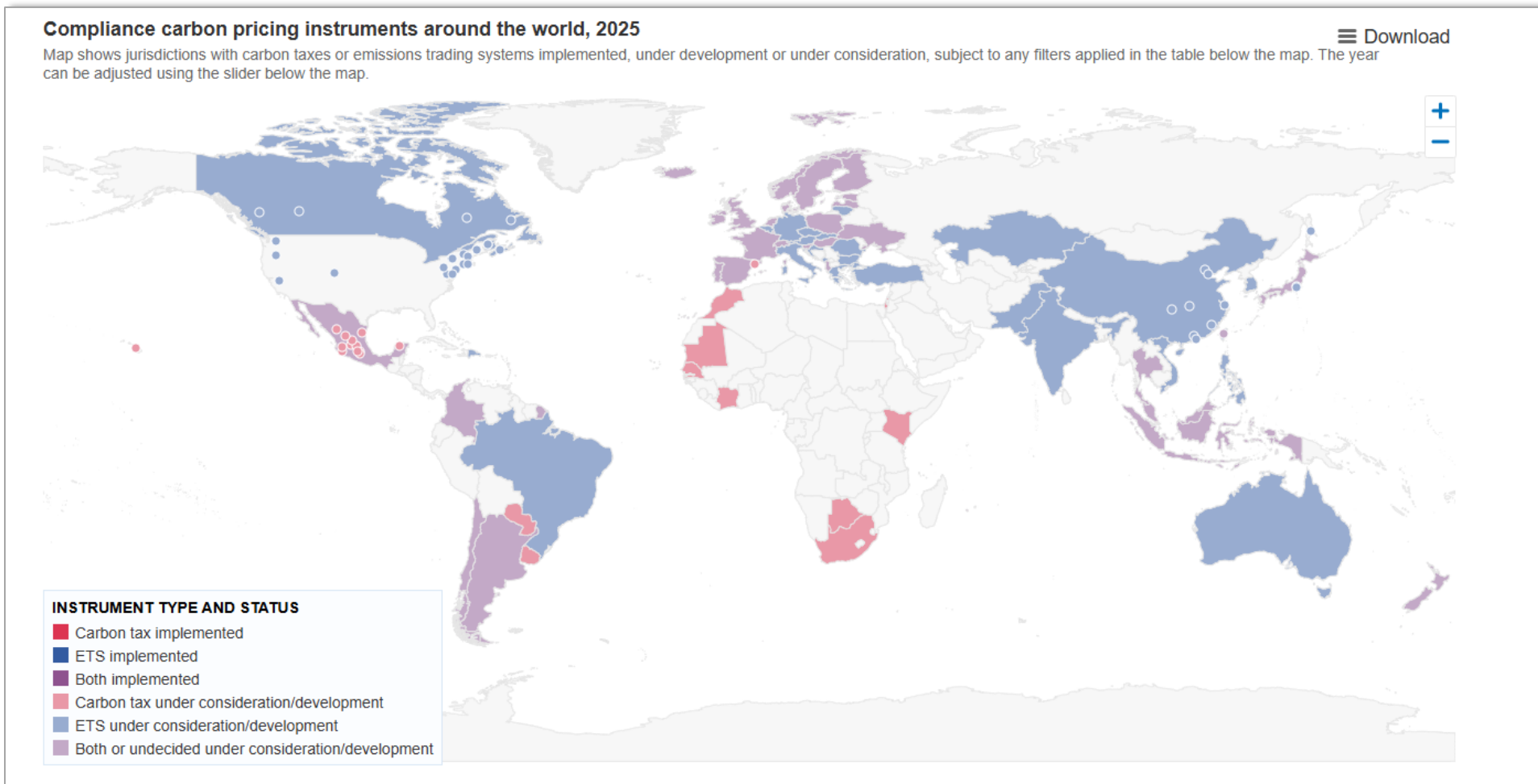
Bioenergy with Carbon Capture and Storage: bioenergy crops at KBS



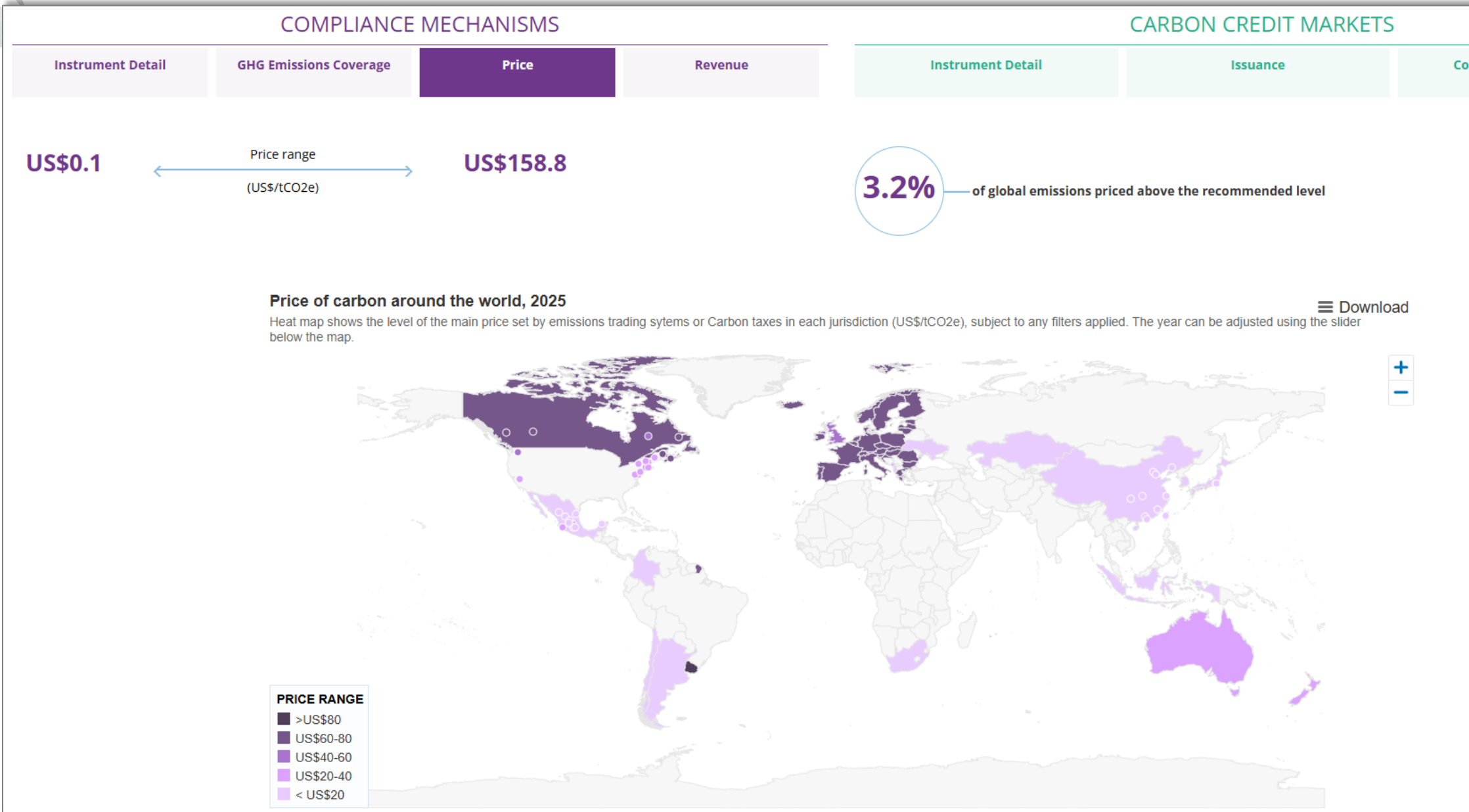
3. Carbon Credit and Stock

[State and Trends of Carbon Pricing Dashboard](https://carbonpricingdashboard.worldbank.org/?utm_source=chatgpt.com) (https://carbonpricingdashboard.worldbank.org/?utm_source=chatgpt.com)

The State and Trends of Carbon Pricing Dashboard is an interactive online tool aimed at policymakers, businesses, and researchers. It provides the latest information on existing and emerging direct carbon pricing initiatives around the world.



3. Carbon Credit and Stock





Take-home-messages

- 1) Carbon emissions driven by population growth and rising energy consumption vary across countries
- 2) Two primary approaches exist for carbon sequestration (natural and artificial), with multiple examples
- 3) Policies and implications are reflected through carbon credit programs



Next lecture (Nov 3)

Quiz 4: carbon related issues

Urban Heat Islands (UHI)