Future Emissions Scenarios

EES 2110

Introduction to Climate Change

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Class #31: Wednesday, March 29 2023

Bathtub model

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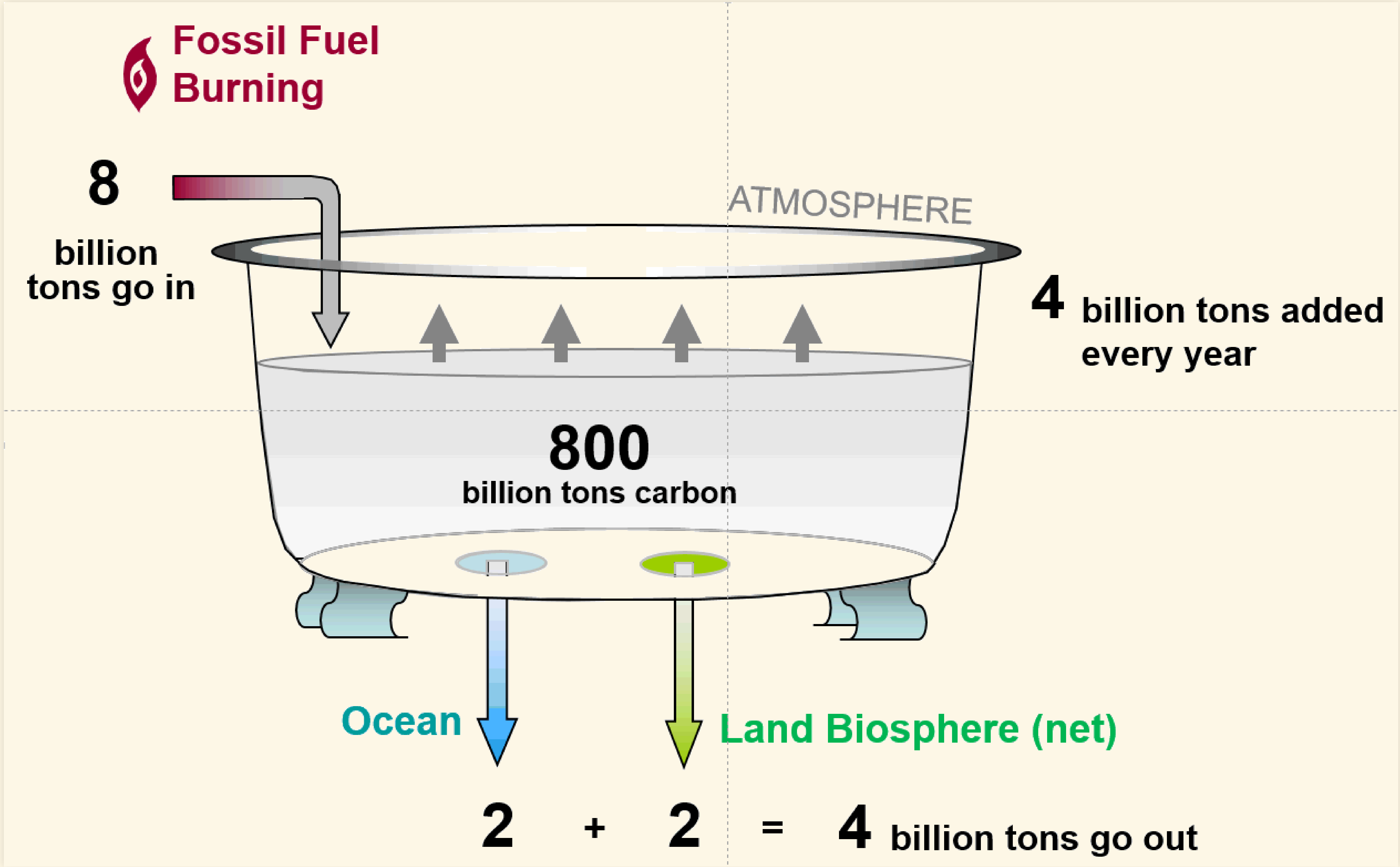
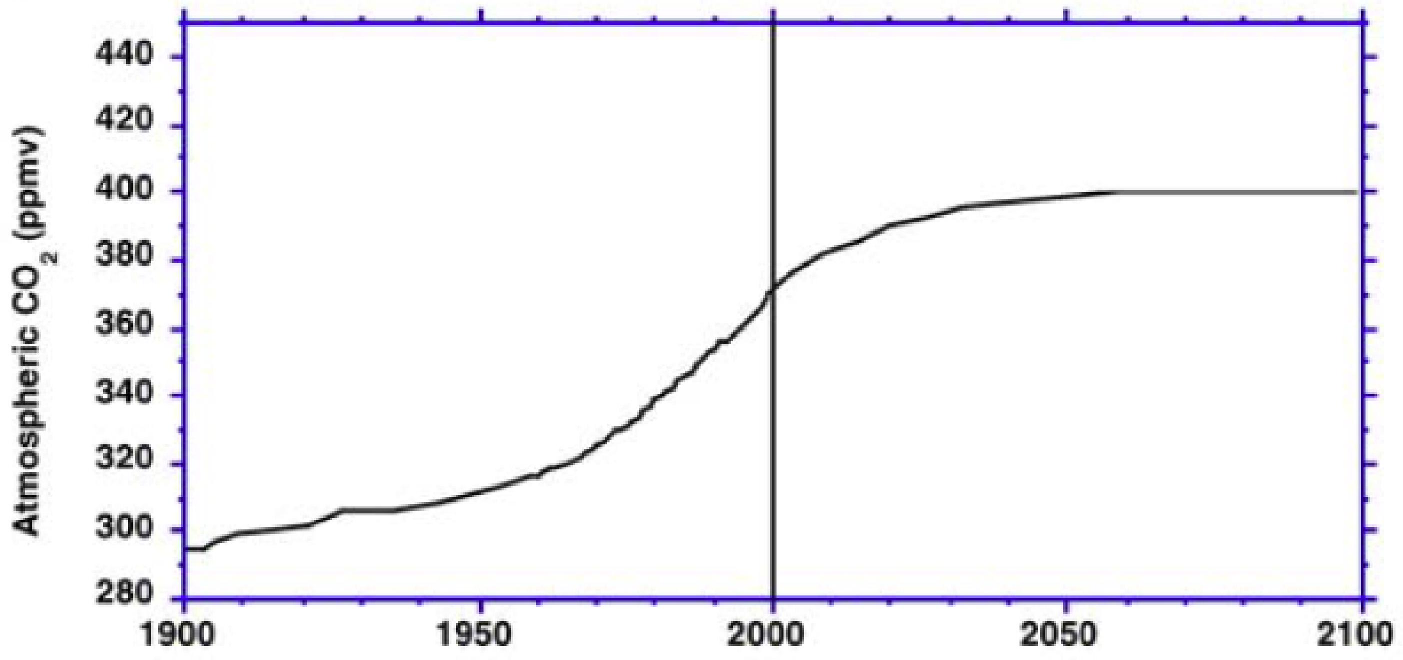
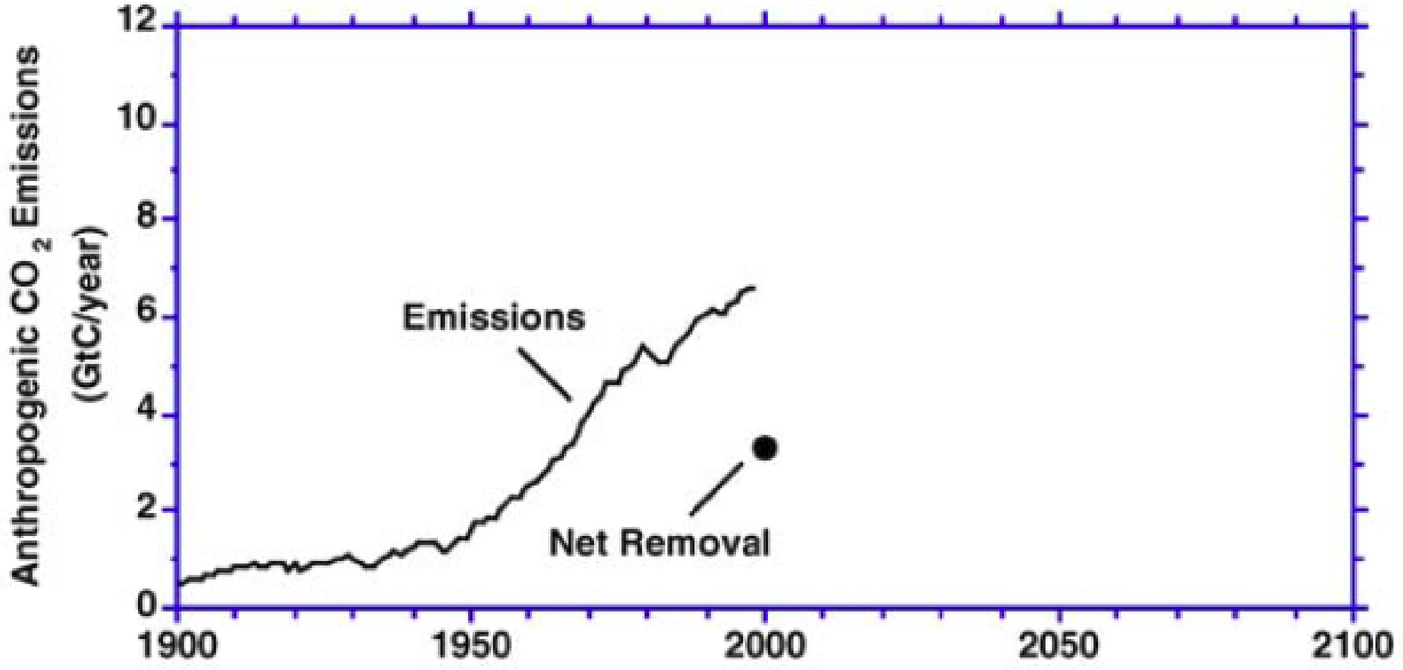


Bathtub model

Now consider a scenario in which the concentration of CO_2 in the atmosphere gradually rises to 400 ppm, about 8% higher than the level today, then stabilizes by the year 2100, as shown here:

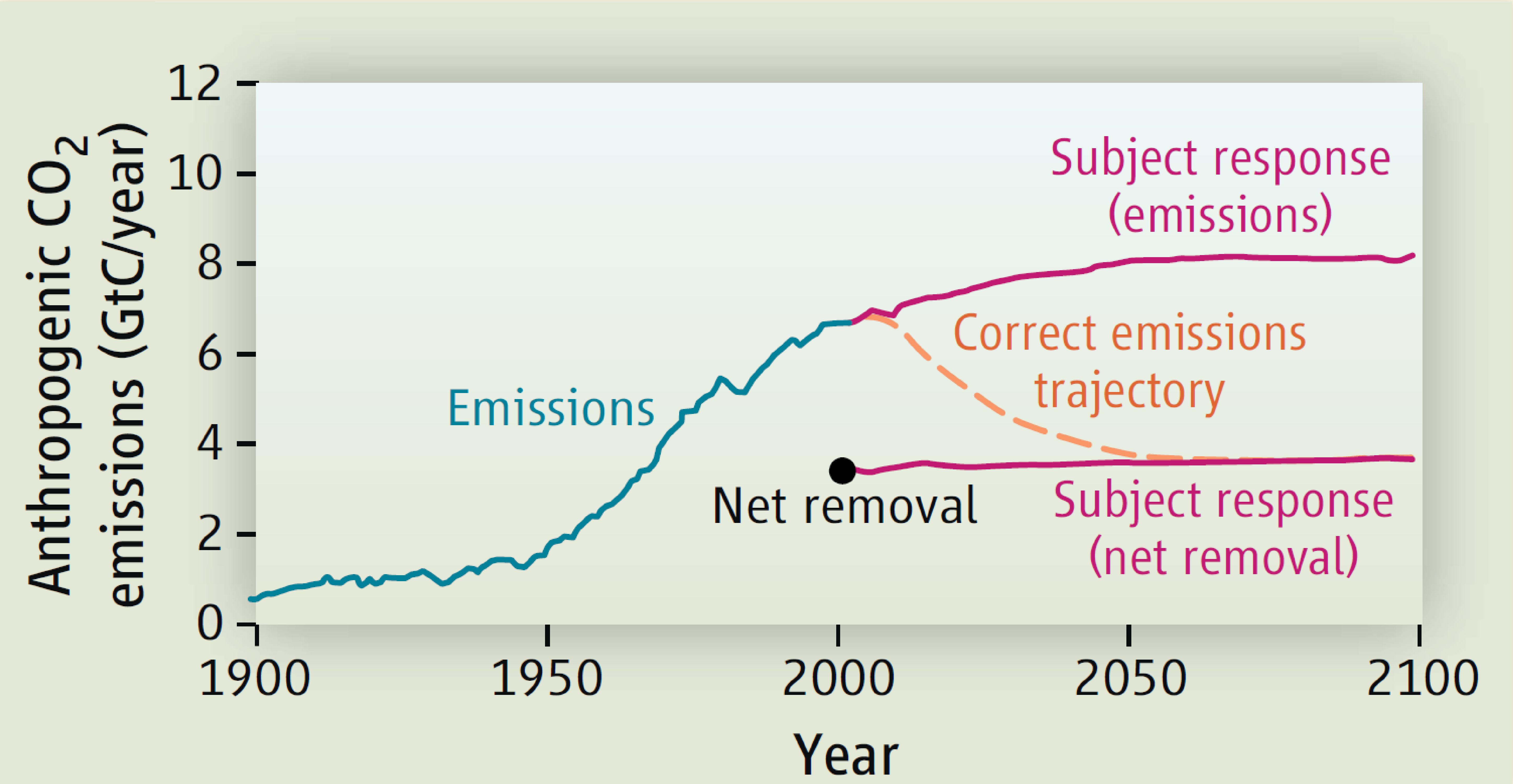


1. The graph below shows anthropogenic CO_2 emissions from 1900-2000, and current net removal of CO_2 from the atmosphere by natural processes. Sketch:
   a. Your estimate of likely future net CO_2 removal, given the scenario above.
   b. Your estimate of likely future anthropogenic CO_2 emissions, given the scenario above.



J.D. Sterman, Science **322**, 532 (2008).

Bathtub model



J.D. Sterman, Science **322**, 532 (2008).

- 212 MIT MBA and graduate students.
- 60% majored in science or engineering

Kaya Identity

Kaya Identity

$$F = P \times g \times e \times f$$

- F = emissions (million tonnes carbon per year)
- P = population (billions)
- g = per-capita GDP ($1000 per person)
- e = energy intensity of economy (quads / trillion dollars)
- f = carbon intensity of energy supply (million tonnes carbon / quad)

Policy

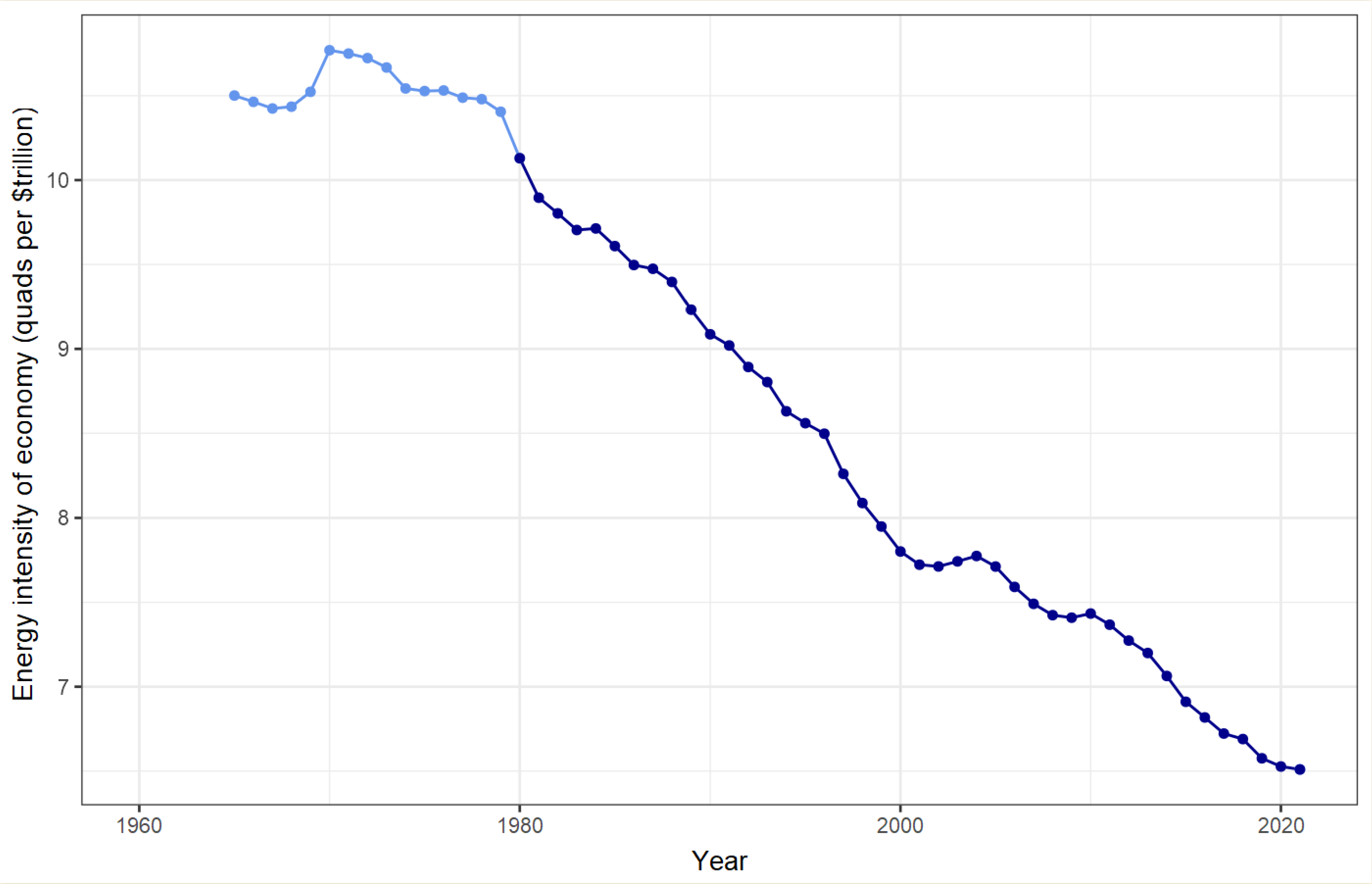
- We can't directly control P
- We want g to grow
- Therefore, decrease e and f

Policy in Practice

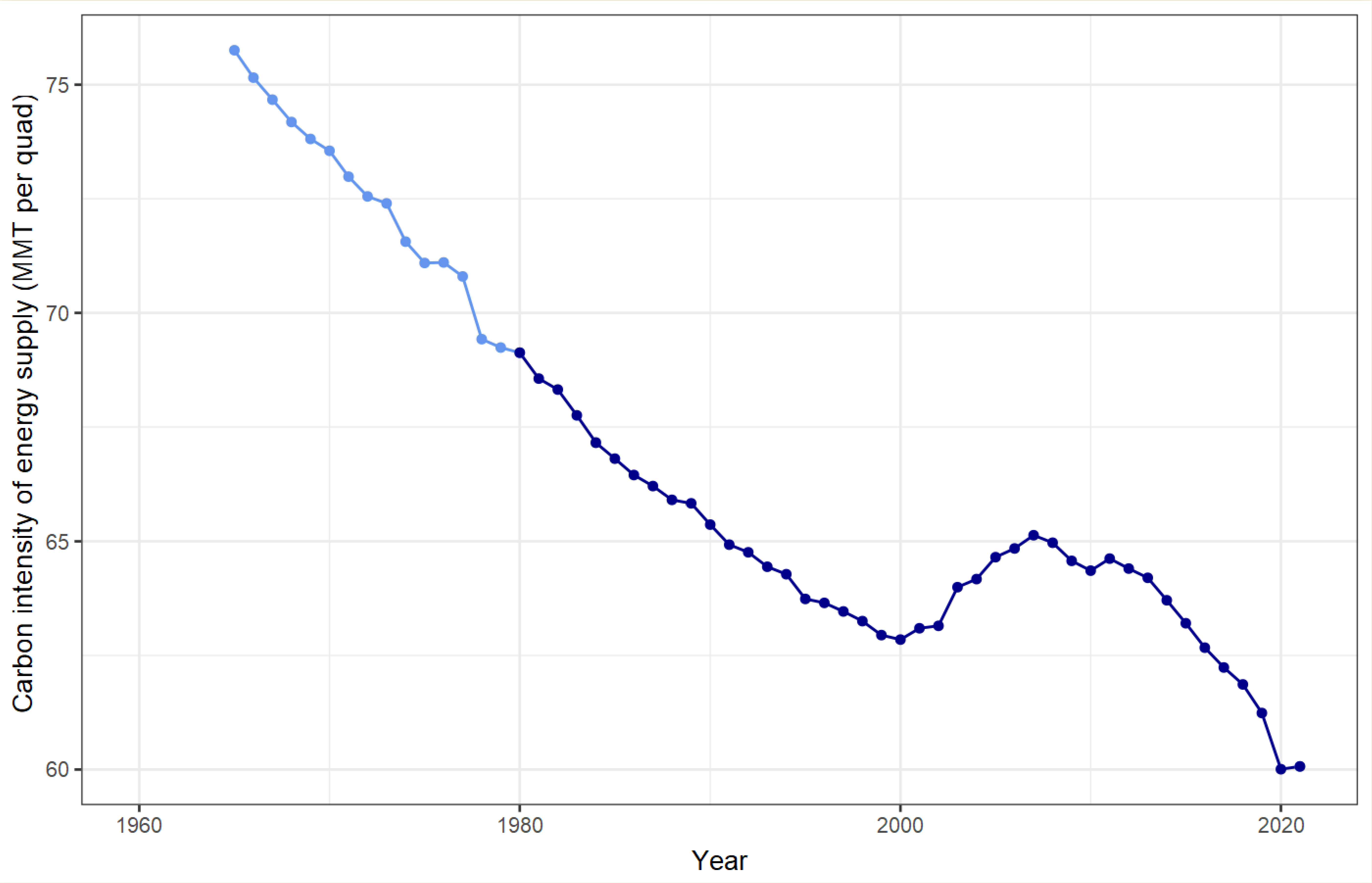
- **Reduce e:**
  - e is the energy intensity of the economy
  - Reducing e means making the economy more energy efficient
    - **Waste less energy**
      - Fossil-fuel electricity generation wastes 1/2 to 2/3 of primary energy
      - Gasoline & diesel cars and trucks waste about 2/3 of primary energy
      - Incandescent light bulb wastes 98% of electric energy
    - **Get more value from the energy we use**
- **Reduce f:**
  - f is carbon intensity of the energy supply
    - Switch from coal to gas
    - Switch from fossil fuels to clean energy
      - Nuclear energy
      - Renewable energy
        - Wind
        - Solar
        - Geothermal
        - …

Recent Trends

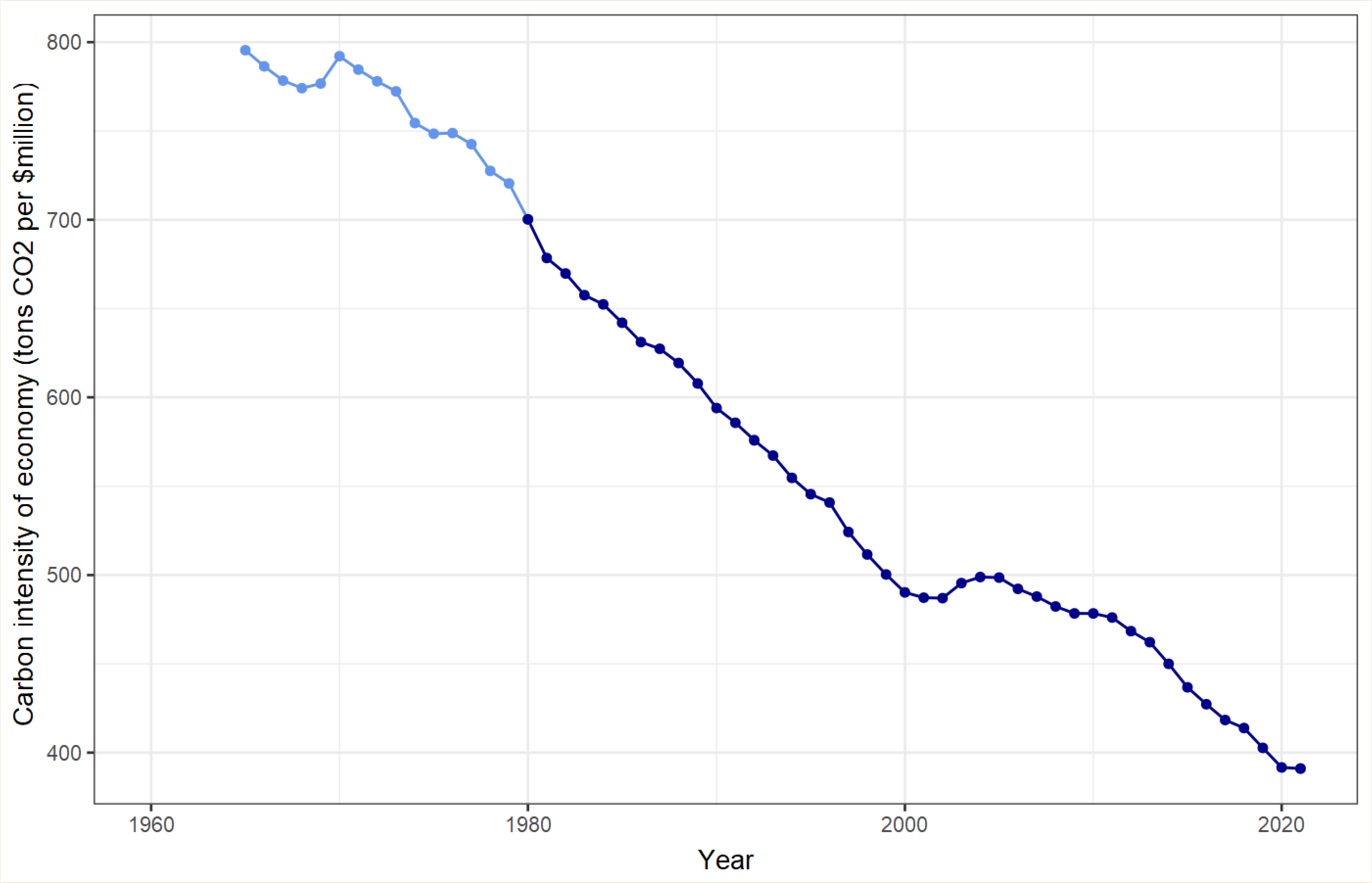
Energy Intensity of Global Economy (*e*)



Carbon Intensity of Global Energy Supply (f)



Emissions Intensity of Global Economy (*ef*)



Progress on Reducing e and f

- From 2005–2021,
  - **e dropped by 16.2%**
    - Examples:
      - Computing data centers became 6 times more energy efficient from 2010–2018.
      - Electric lighting became 4 times more energy efficient since 2007.
      - Cars and light trucks use 20% less fuel than in 2005.
  - **f dropped by 7.6%**
    - Big shift from coal to gas because of "fracking".
    - Wind and solar are the fastest-growing sources of electricity
- But we need to speed up these trends to meet world climate goals

Implied Decarbonization

Implied Decarbonization

- Specify emissions for 2050, compared to 2021
- Assume global GDP G grows at rate r ($5\% \to r = 0.05$)

$$\text{emissions: } F = Pgef = G \times ef$$
$$F(2050) = G(2050) \times ef(2050)$$

Growth:

$$\begin{aligned} y(\text{5 years from now}) &= y(\text{today}) \times \exp(r \times 5) \\ &\approx y(\text{today}) \times (1 + r)^5 \end{aligned}$$

- exp = exponential function (e^x).
- Call it “exp” to avoid confusing e in Kaya formula with e, base of natural logarithm.

Implied Decarbonization

- Specify emissions for 2050, compared to 2021
- Assume global GDP G grows at rate r ($5\%\% \rightarrow r = 0.05$)

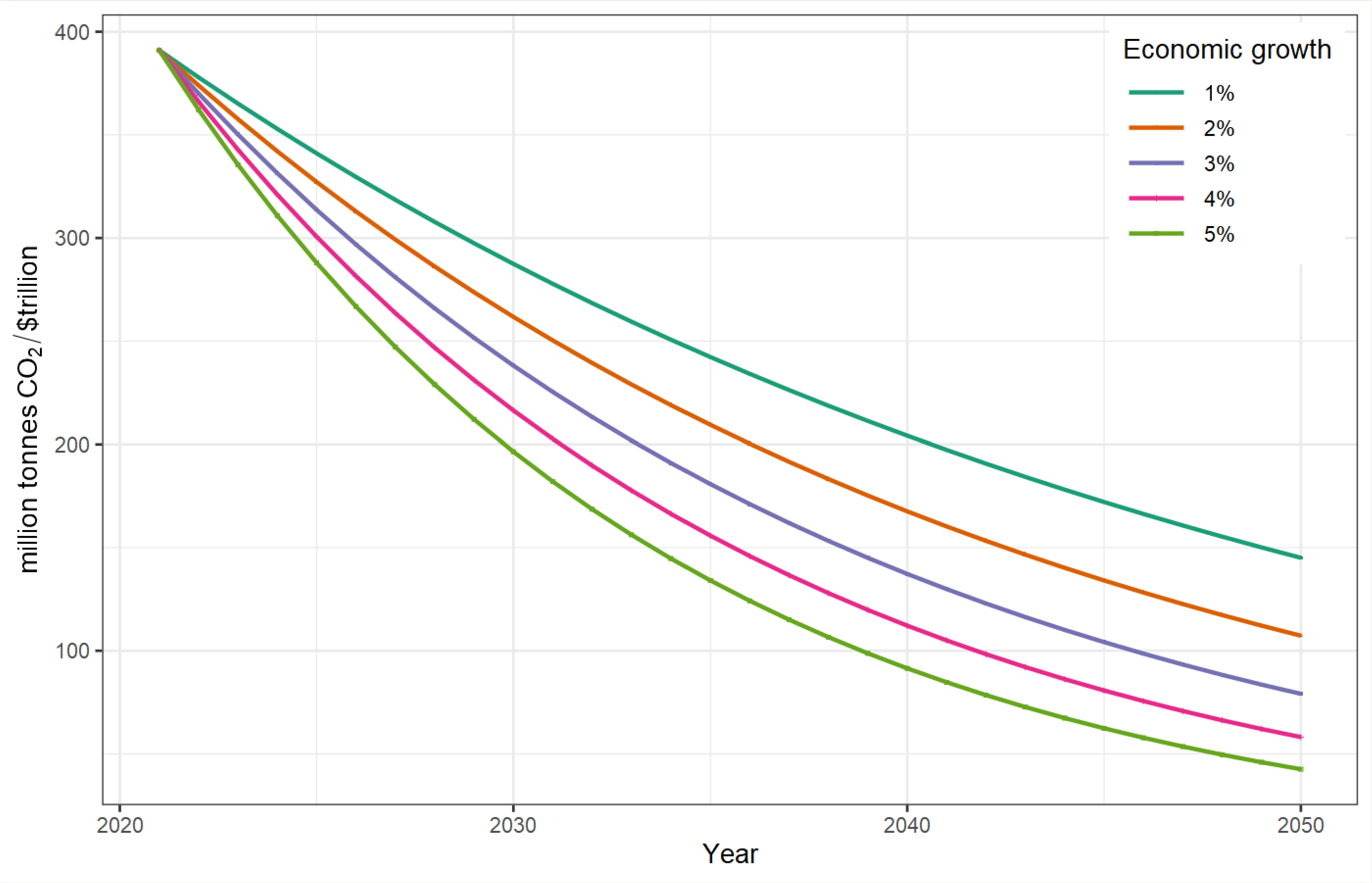
$$\text{emissions: } F = Pgef = G \times ef$$

$$F(2050) = G(2050) \times ef(2050)$$

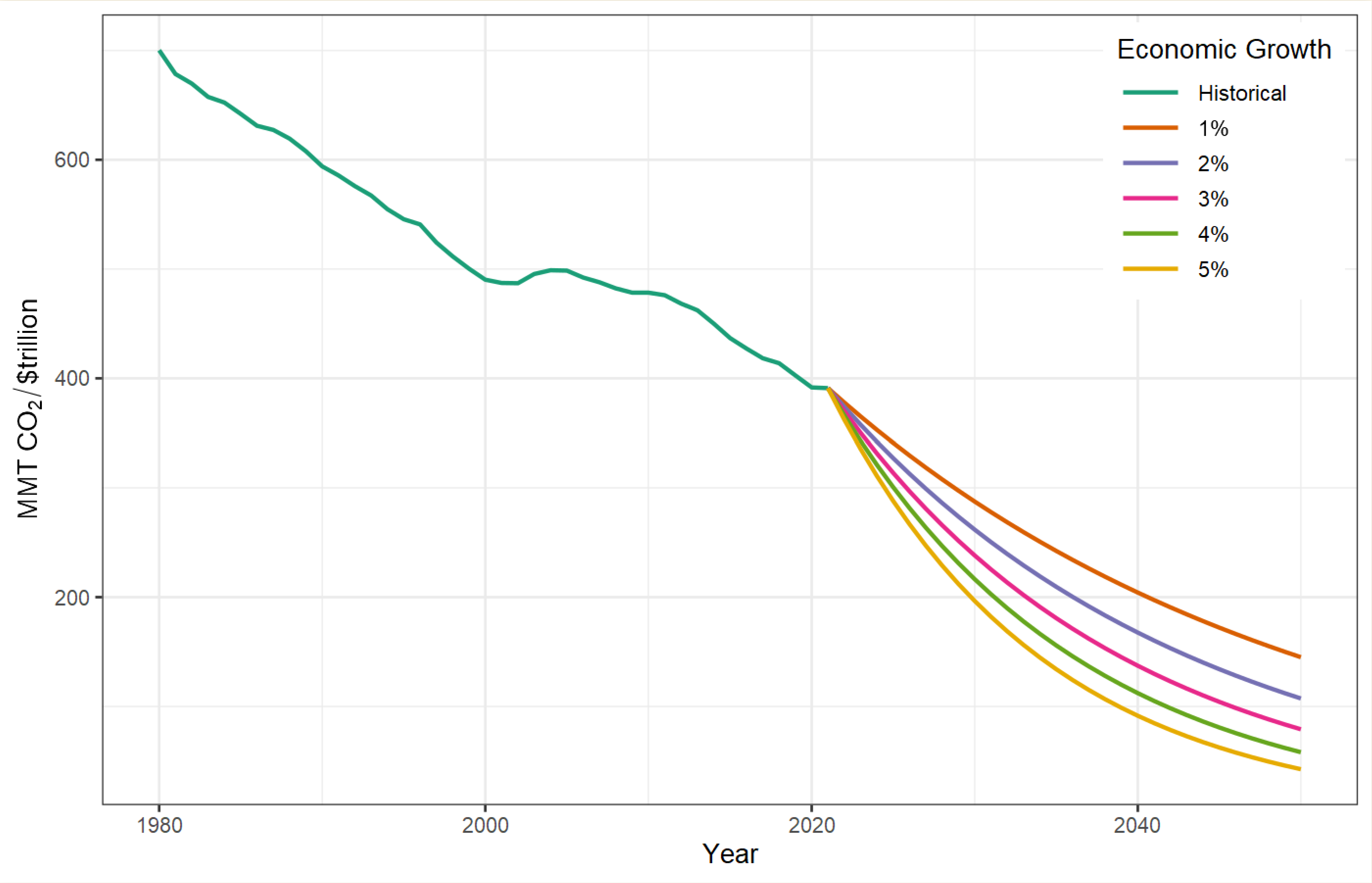
$$G(2050) = G(2021) \times \exp(r \times (2050 - 2021))$$

$$\begin{aligned} ef(2050) &= \frac{F(2050)}{G(2050)} \\ &= \frac{F(2050)}{G(2021) \times \exp(r \times 29)} \approx \frac{F(2050)}{G(2021) \times (1 + r)^{29}} \end{aligned}$$

Reduce emissions 50% by 2050:



Actual and Implied Decarbonization



Pielke’s Policy Criteria

1. Policies should flow with public opinion
2. Public will not tolerate significant short-term costs, even for big long-term benefits
3. Policy must center on clean energy innovation

Play with Decarbonization

Interactive Tool

https://ees2110.jgilligan.org/decarbonization/

Decarbonization Explorer

Country/Region

Target year

2050

Emissions reduction (%)

80

Reference year for emissions reduction

1990

Calculate trends starting in

1980

Trends | Calculations | Implied Decarbonization | Energy Mix | Historical

Variable

P