Top-Down Decarbonization

EES 3310/5310

Global Climate Change

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Class #26: Monday Oct. 22 2018

Announcement

No office hour today (Monday)

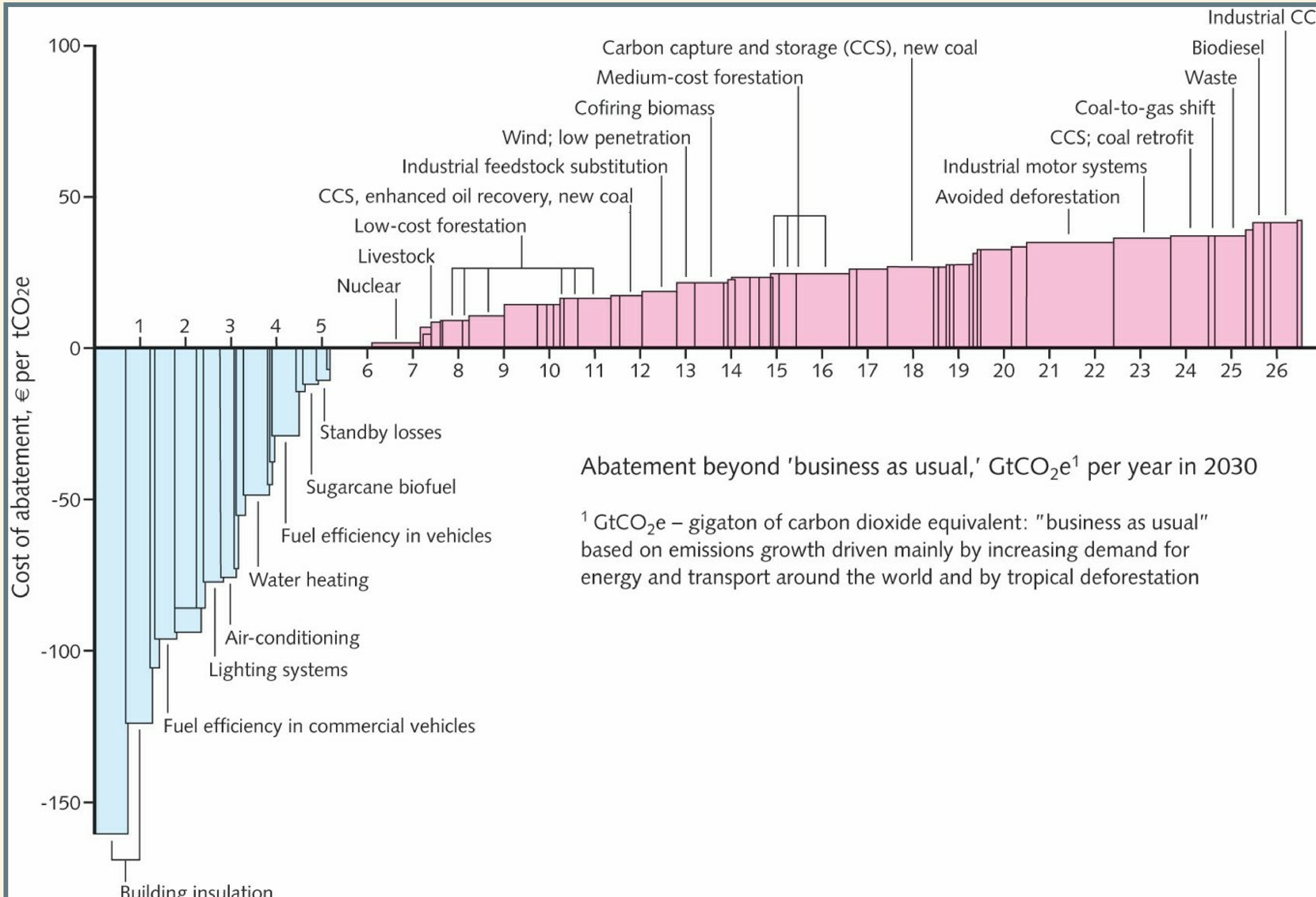
Considerations on Projections of Future Emissions

Grain of Salt

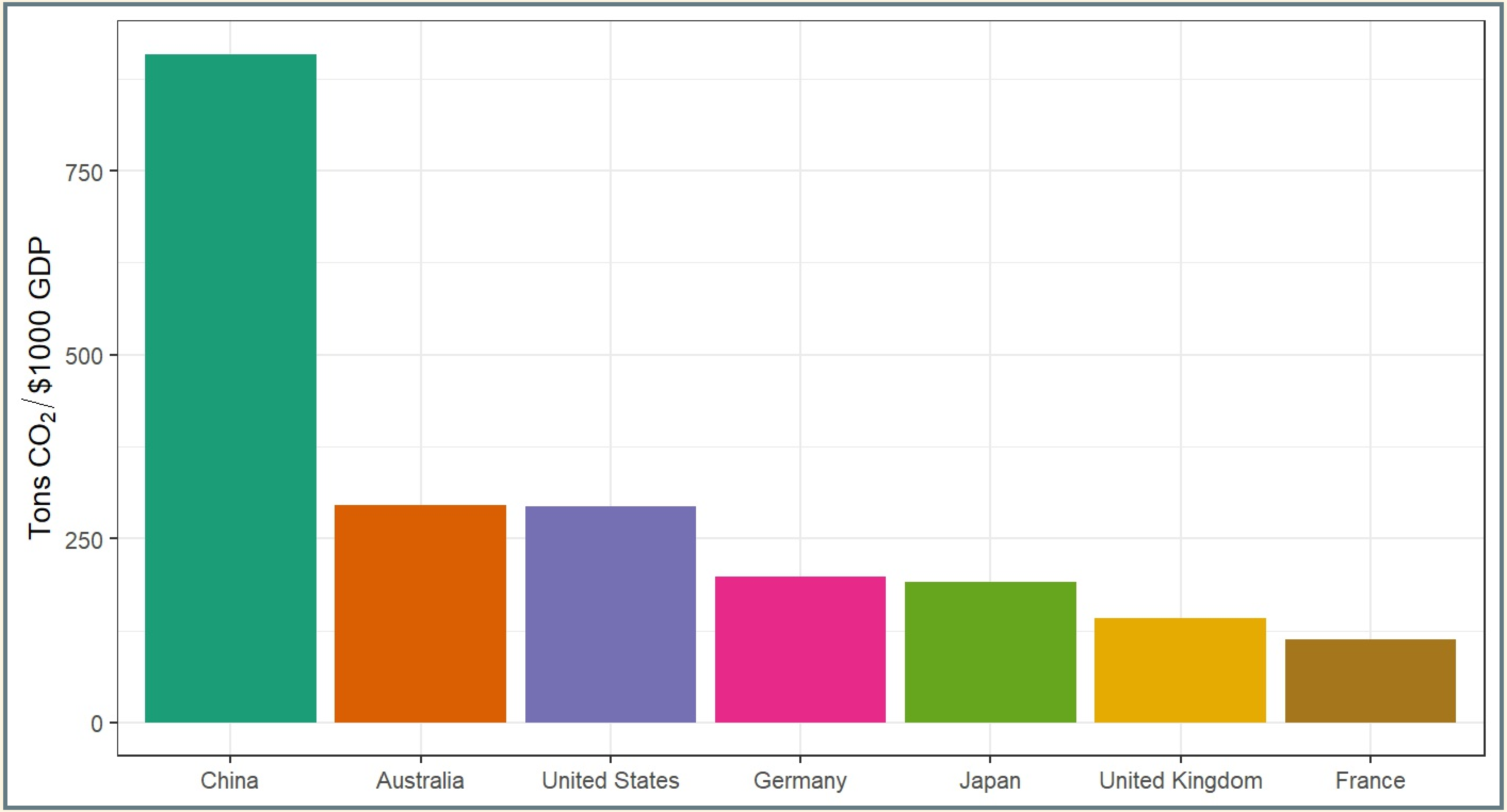
- Implied decarbonization rates depend on predictions of P, G, etc.
- Predicting population and economic growth are very tricky and imprecise.
- So take any of these calculations with a grain of salt.
- But are they still useful, despite the uncertainties?

How Can We Decarbonize?

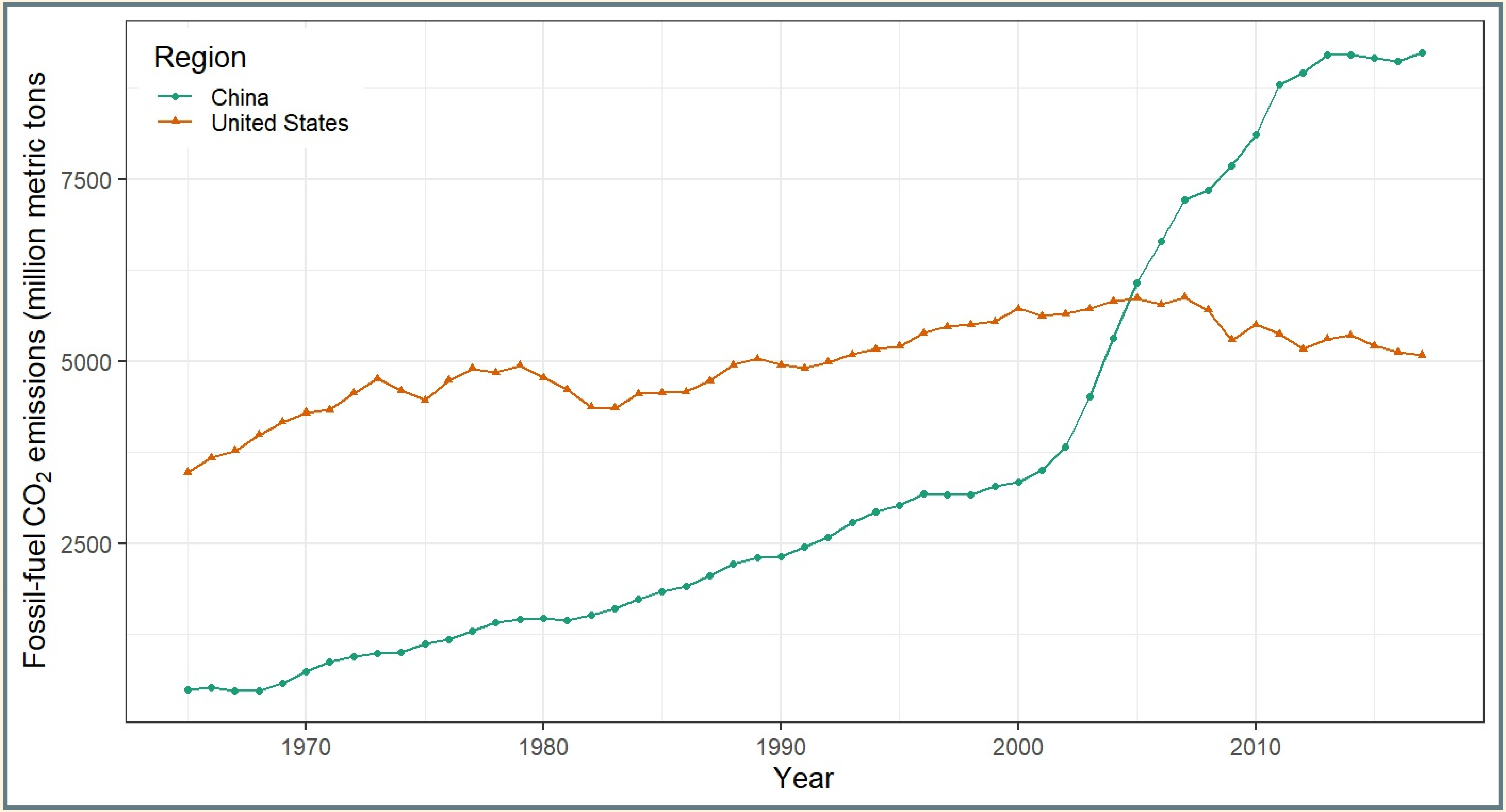
Detailed Abatement Options



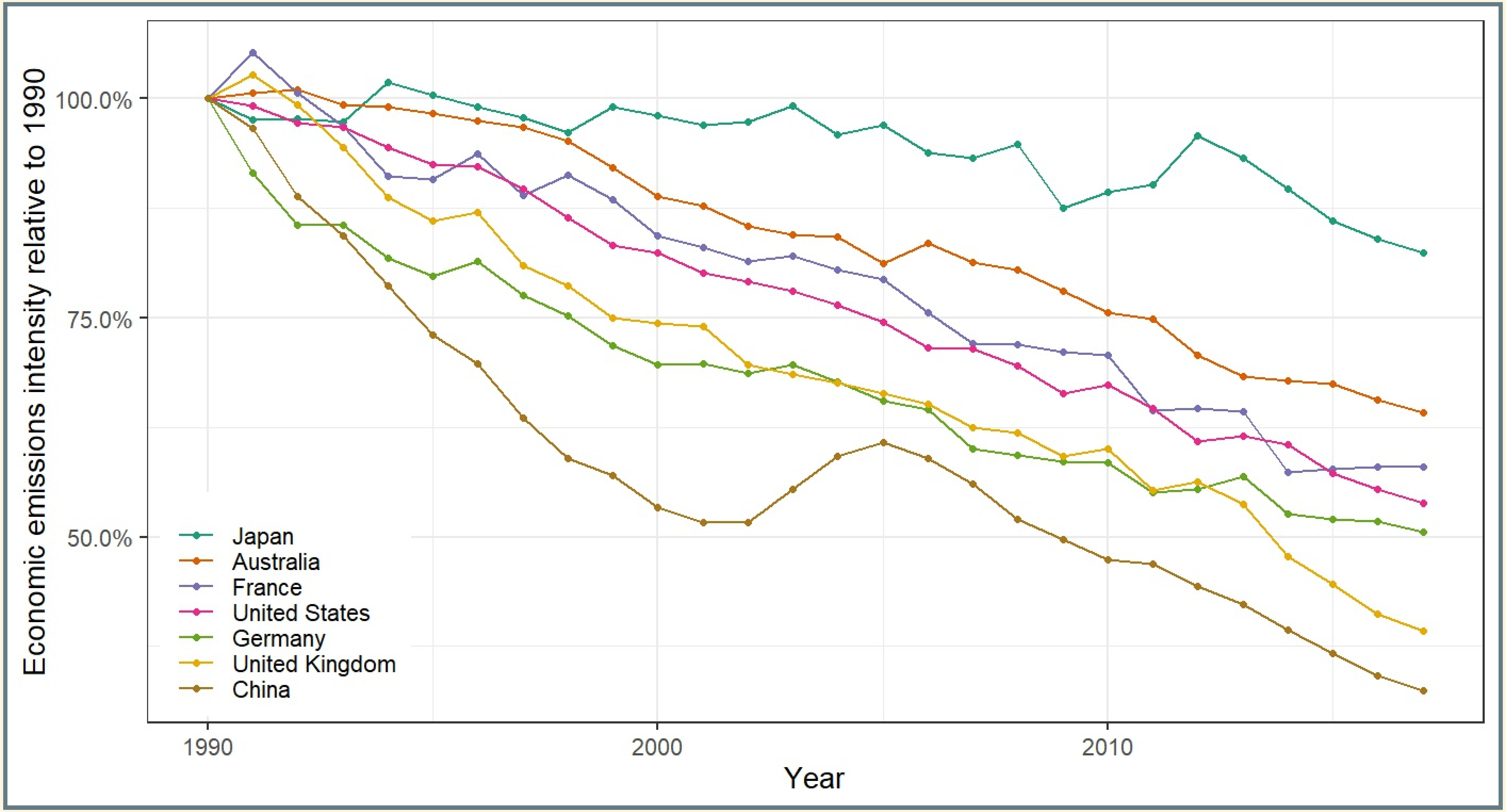
Economic Carbon Intensity in 2017



CO_2 Emissions 1965–2017



Relative improvement in carbon intensity 1990–2017

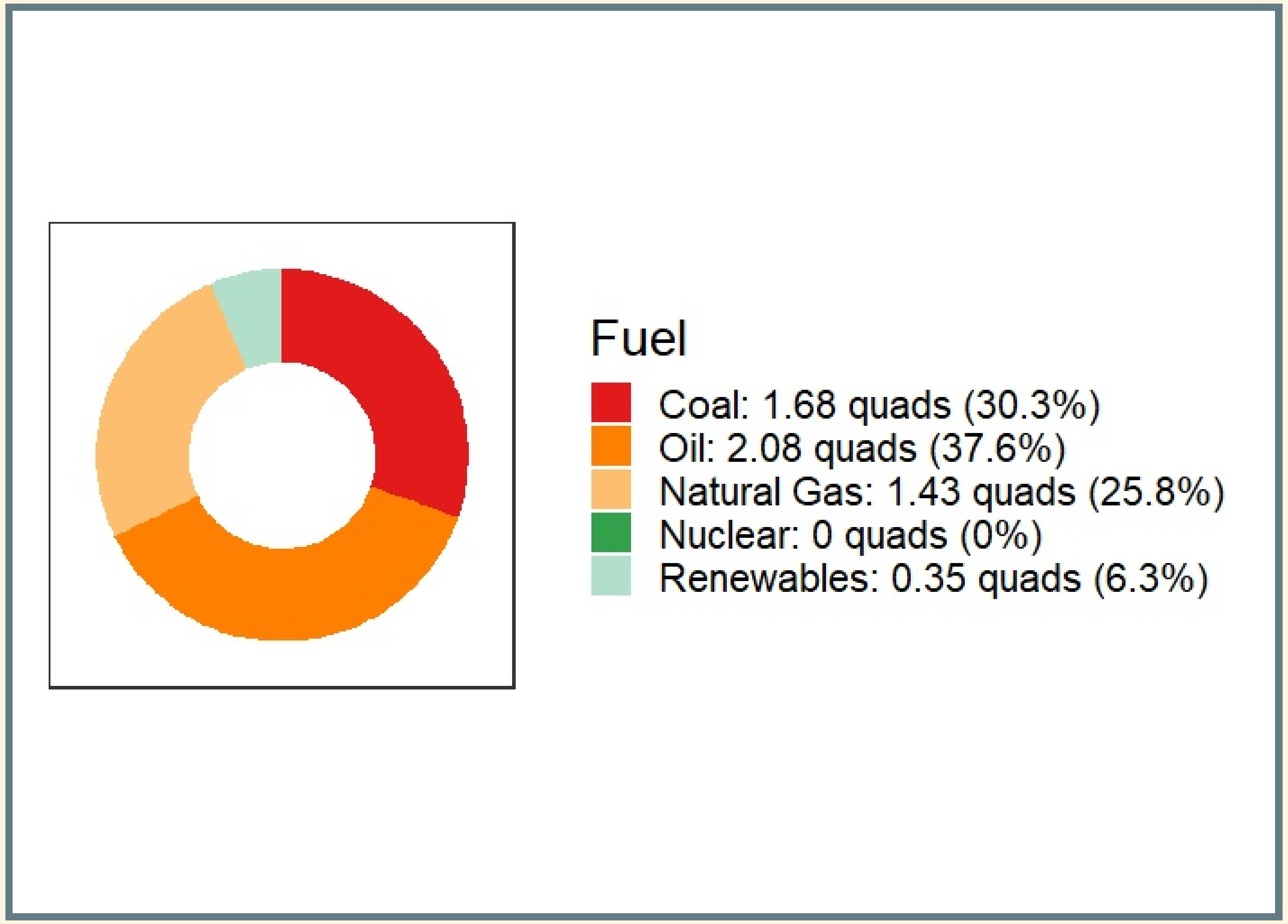


Top-Down Analysis for Australia

Projected Energy Use in 2050

- Energy Information Administration top-down projection for energy demand in Australia in 2050:
  - Total 2050 Primary Energy Use = 9.44 Quads
  - Assume *P*, *g*, and *e* are fixed.
  - Manage emissions by reducing *f*
    - switch from fossil fuels to clean energy

Energy Mix in 2017



Fuel	Quads	%
Coal	1.68	30.3
Natural Gas	1.43	25.8
Oil	2.08	37.6
Nuclear	0.00	0.0
Renewables	0.35	6.3
Total	5.53	100.0

Emissions Factors

Fuel	**MMT CO_2 per Quad**
Coal	94
Oil	70
Natural Gas	53
Nuclear	0
Renewables	0

Projected Business as Usual Emissions in 2050

Fuel	**%**	**Quads**	**MMT/Quad**	**MMT CO_2**
Coal	30	2.86	94	270
Natural Gas	26	2.44	53	129
Oil	38	3.55	70	248
Nuclear	0	0.00	0	0
Renewables	6	0.60	0	0
Total	100	9.44	NA	648

Top-down emissions-reduction

Fuel	%	Quads	MMT/Quad	MMT CO_2
Coal	30	2.86	94	270
Natural Gas	26	2.44	53	129
Oil	38	3.55	70	248
Nuclear	0	0.00	0	0
Renewables	6	0.60	0	0
Total	100	9.44	NA	648

- Projected emissions for 2050 (no change in *f*): 578 MMT
- Emissions goal for 2050 = 139 MMT
- Must cut by (578 - 139) = 439 MMT
- Start with coal:
  - Cut 270 MMT (2.86 quads)
  - 169 MMT left
- Next, cut gas:
  - Cut 129 MMT (2.44 quads)
  - 40 MMT left
- Finally, cut oil:
  - Cut 40 MMT (0.57 quads)
- Total energy cuts = 2.86 + 2.44 + 0.57 = 5.87 quads.

Clean Energy Sources

- 11,000 megawatts (MW) for one year = 1 quad
  - (See Climate Fix, p. 97)
- **Nuclear Power Plant**:
  - 1000 MW × 75.0%% efficiency = **750 MW average**
  - 1 quad per year = 11,000 MW / (750 MW per nuclear plant) = **14.7 nuclear plants**
- **Concentrated Solar Power**:
  - 10 MW × 33.0%% efficiency = **3 MW average**
  - **1 quad = 3,300 concentrated solar-thermal plants**
- **Wind Turbine**:
  - 2.5 MW × 33.0%% efficiency = **1 MW average**
  - **1 quad = 13,300 wind turbines**

Meeting Australia's Goal

- Cut CO_2 by 439 MMT
  - 270 MMT from coal (2.86 quad)
  - 129 MMT from gas (2.44 quad)
  - 40 MMT from oil (0.57 quad)
- Total clean energy needed: quads per year

- 5.87 quads × 14.7 nuclear plants/quad = **86 nuclear power plants** in 33 years (2.6 per year)
- 5.87 quads × 3,300 concentrated solar plants/quad = **19,365 concentrated solar plants** in 33 years (587 per year, or 11 per week)
- 5.87 quads × 13,300 wind plants/quad = **78,047 wind turbines** in 33 years (2,365 per year, or 6 per day)

Pielke's Bottom Line

- Unfeasible to build so much clean energy so quickly
- Expense of building so much clean energy would defeat Australia's economic goals
- This is why we don't have the technology to decarbonize as quickly as politicians and activists have been promising.

But …

- Australia used 5.53 quads in 2017.
- If it uses 9.44 quads in 2050,
  - Extra 3.91 quads
  - 14.7 coal-fired power plants per quad
  - 57 new coal-fired plants (1.7 new coal plants per year)
- Costs of building new fossil capacity
  - Costs of coal, ash disposal, etc.
  - Public health: illness, death from air pollution

Review

Bottom-Up Analysis

- Start with individual Kaya-identity variables:
  - P, g, e, f
  - Figure out historical rates of change for each
- Gross Domestic Product: $G = P \times g$
  - Rate of change of G: $r_G = r_P + r_g$
  - Rate of change of a product is the sum of the rates of change of the factors
  - Use rate of change of G to extrapolate G in the future:

$$G(2050) = G(2017) \times exp(r_G \times (2050 - 2017))$$

Bottom-Up Analysis

- Start with individual Kaya-identity variables
- Gross Domestic Product: $G = P \times g$
- Figure out implied rate of change of emissions F:
  - Policy: reduce emissions in 2050 60% below 2000:

$$F(2050) = (1 - 0.60) \times F(2000)$$

  - Figure out change in F from this year:

$$r_F = \frac{\ln\left(\frac{F(2050)}{F(2017)}\right)}{2050 - 2017}$$

- Figure out implied rate of decarbonizing the economy:
  - Carbon intensity of the economy is $ef = F/G$.

$$r_e f = r_F - r_G$$

- Compare implied rate of decarbonization to historical trend to assess the difficulty of meeting the policy goals.

Top-Down Analysis

- Start with macroeconomic estimate of future energy demand *E*
- Use mix of energy sources and emissions factors to calculate future emissions (*F*) if the mix of energy sources does not change.
- Calculate policy goal for *F* the same way as for bottom-up analysis
  - (this is purely a comparison of the policy goal to today's emissions)
- Calculate difference between projected future *F* and policy goal for *F*.
- Calculate how many quads of fossil-fuel energy you would have to replace with clean energy to meet the policy goal.
  - Start with cutting coal, then cut natural gas, and finally cut oil
  - Why?
- Figure out how many power plants of different kinds you would have to build to supply the necessary clean energy.
  - Remember that the actual average power output is the nameplate power times the duty factor (also called the efficiency).