

Controlling Carbon in the U.S. Electricity Sector

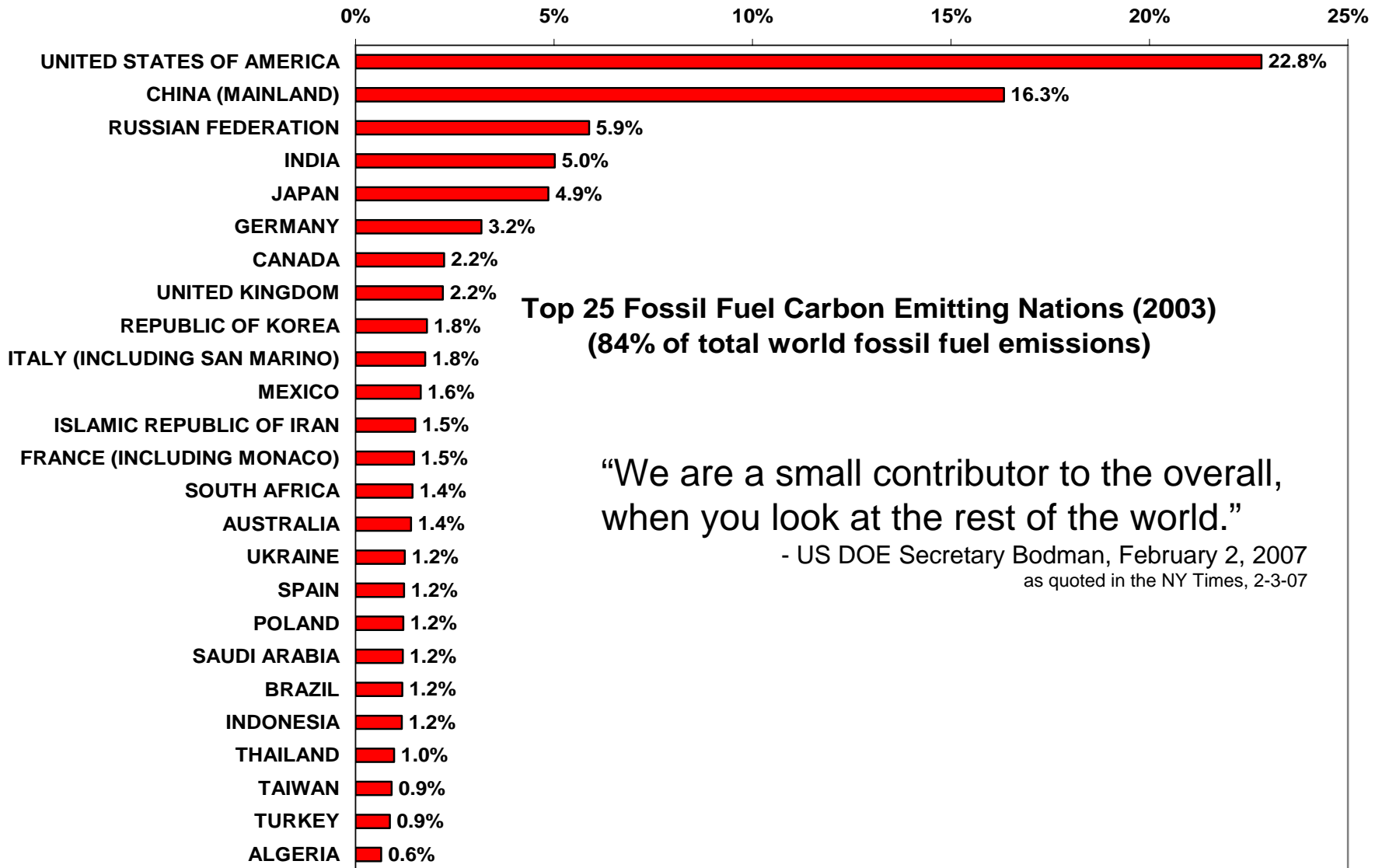
Jay Apt

**Department of Engineering & Public Policy and Tepper School of Business
Carnegie Mellon University**

This afternoon, I will discuss

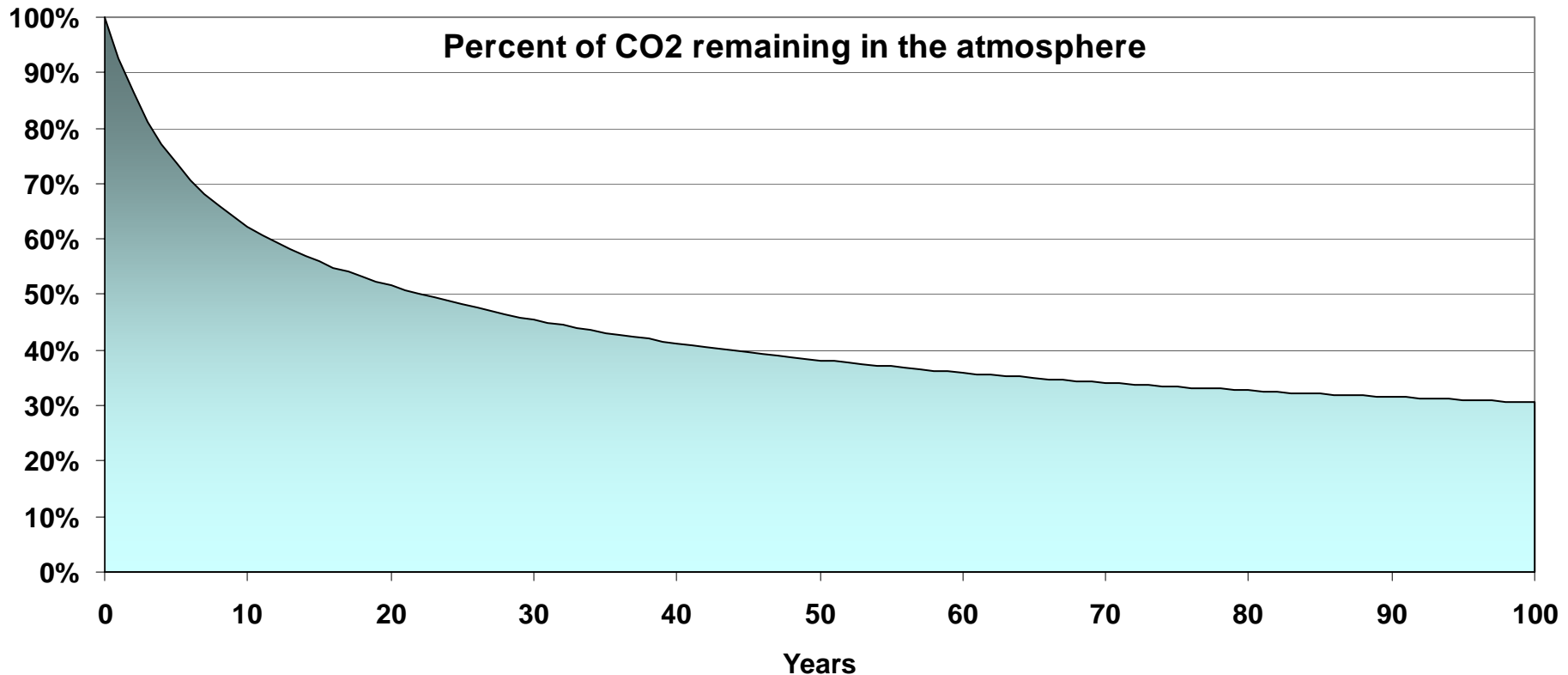
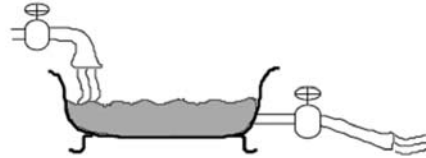
- Briefly, why US action matters
- Why the US electricity sector matters
- Whether low-carbon electricity is affordable
- What drives investment decisions
- How social and private goals can be aligned

2003 Carbon Emissions from Fossil Fuels

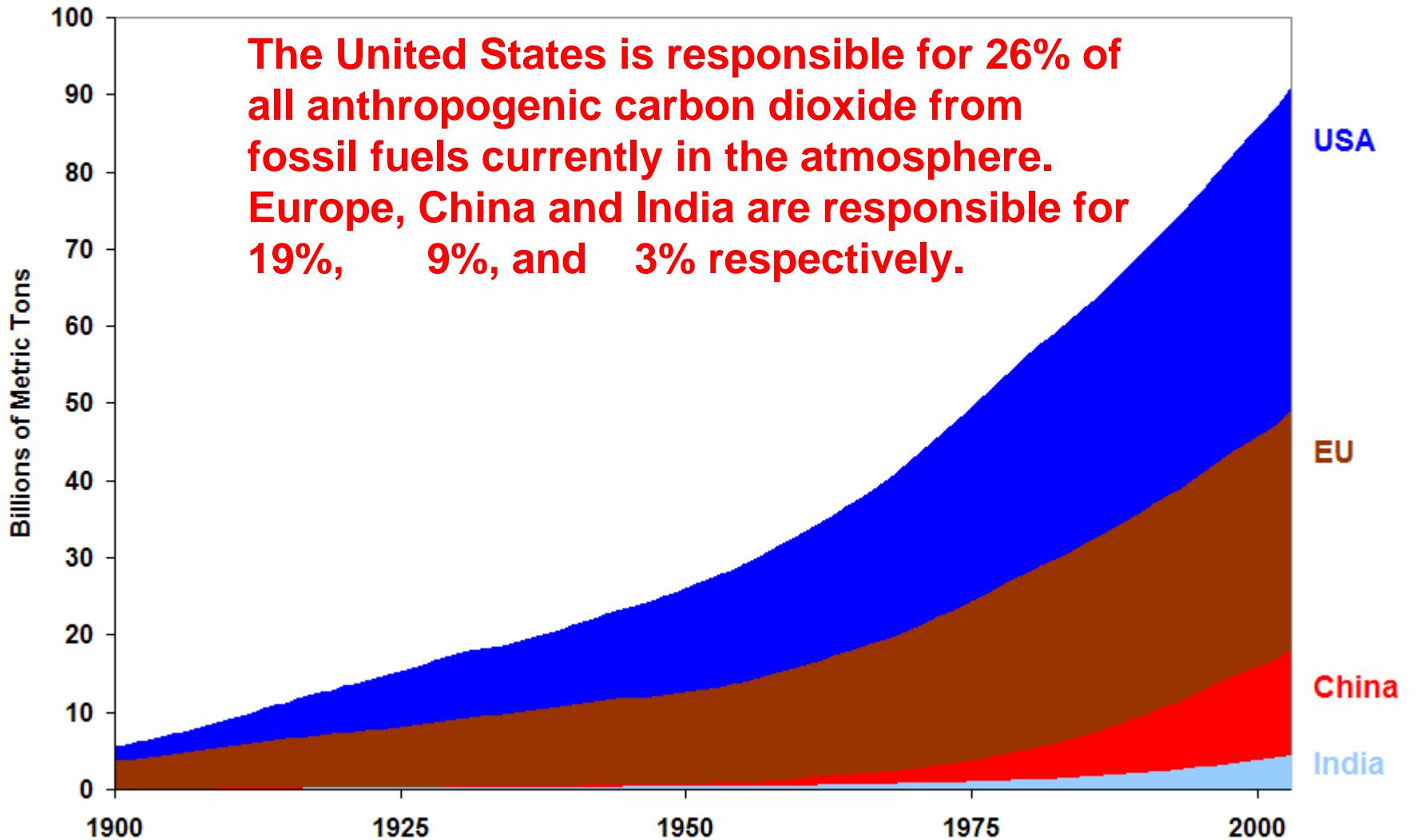


But – carbon remains in the atmosphere

This is a stock-and-flow problem, so intuition about emissions does not give a good picture of concentration.



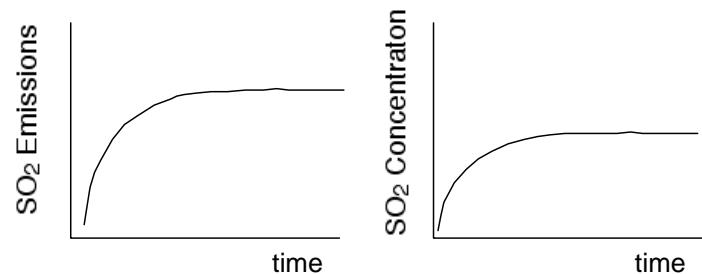
Atmospheric Fossil Fuel CO2 Total Attribution by Nation



The United States is responsible for 26% of all anthropogenic carbon dioxide from fossil fuels currently in the atmosphere. Europe, China and India are responsible for 19%, 9%, and 3% respectively.

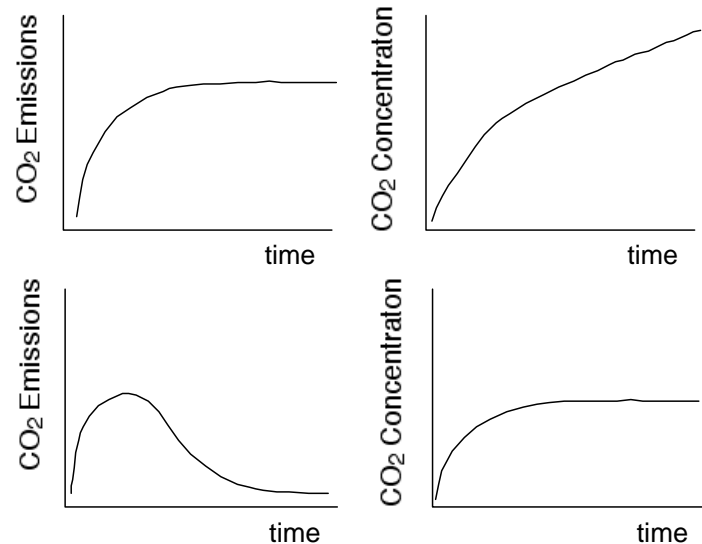
Greenhouse gases are not like conventional pollutants

Conventional pollutants like SO_2 or NO_x have a residence time in the atmosphere of just a few hours or days. Thus, stabilizing emissions of such pollutants results in stabilizing their concentration.

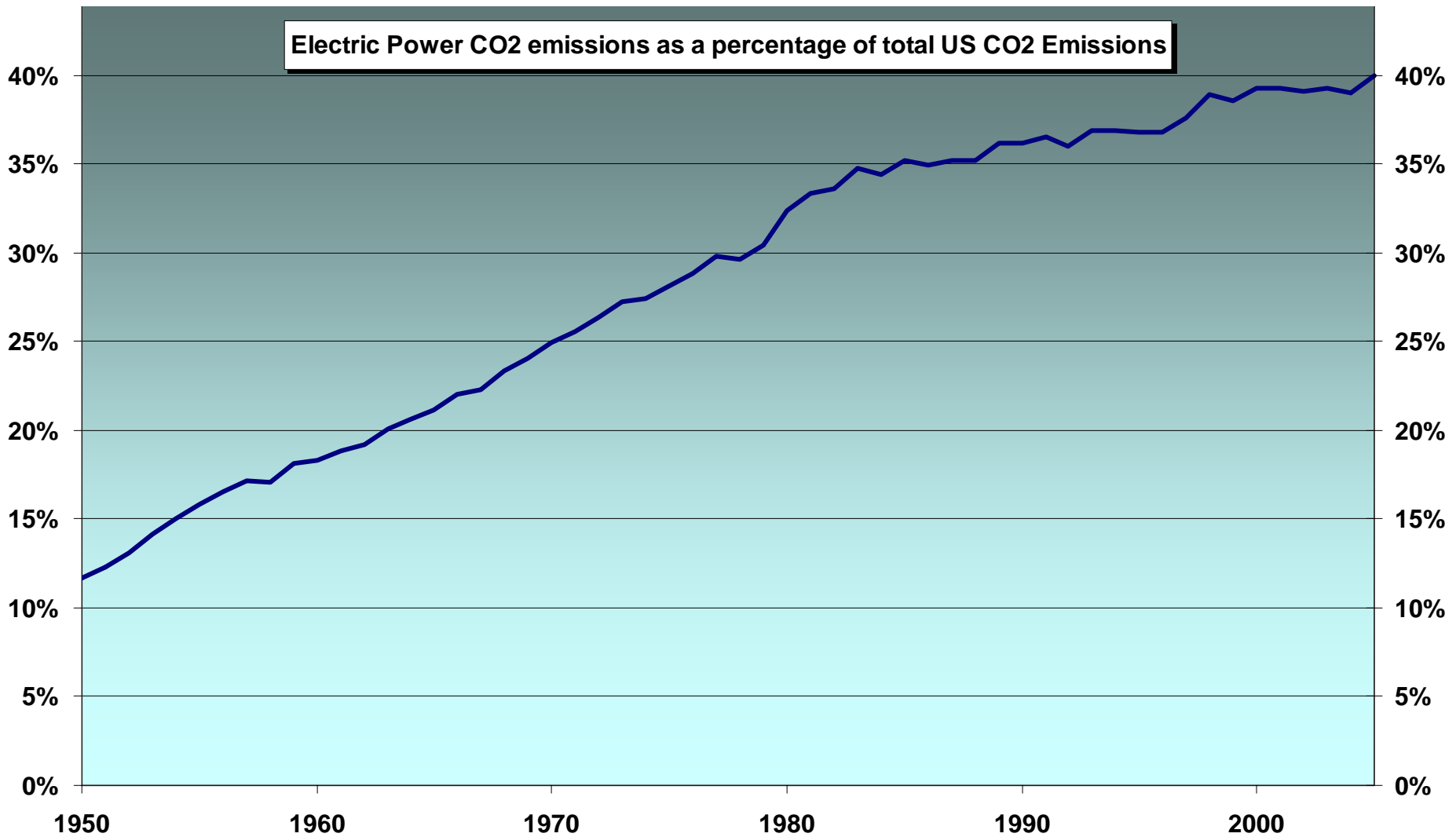


This is not true of carbon dioxide or most other greenhouse gases.

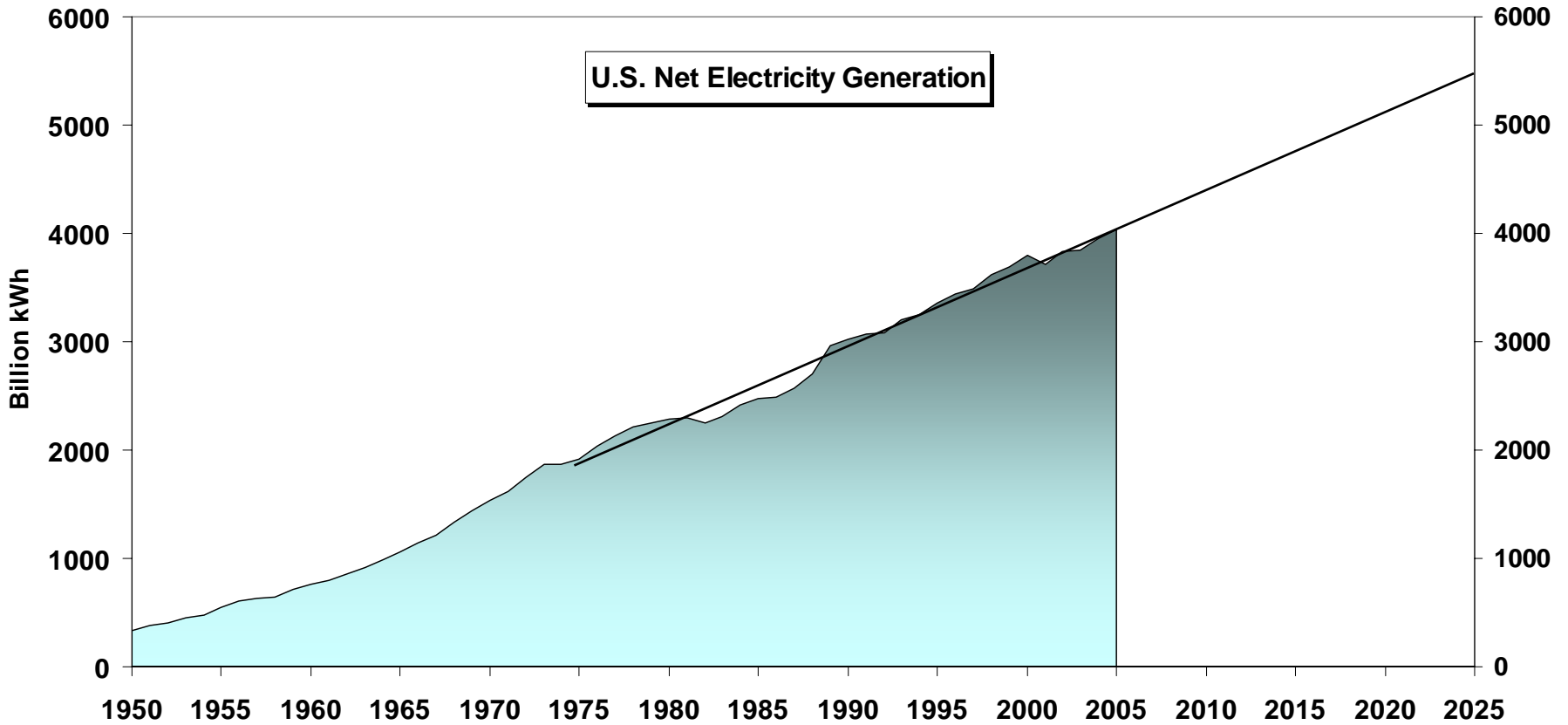
Because CO_2 lasts >75 years in the atmosphere, stabilizing atmospheric *concentrations* of CO_2 will require reductions in current emissions *of at least 80%*.



Why target electric power?



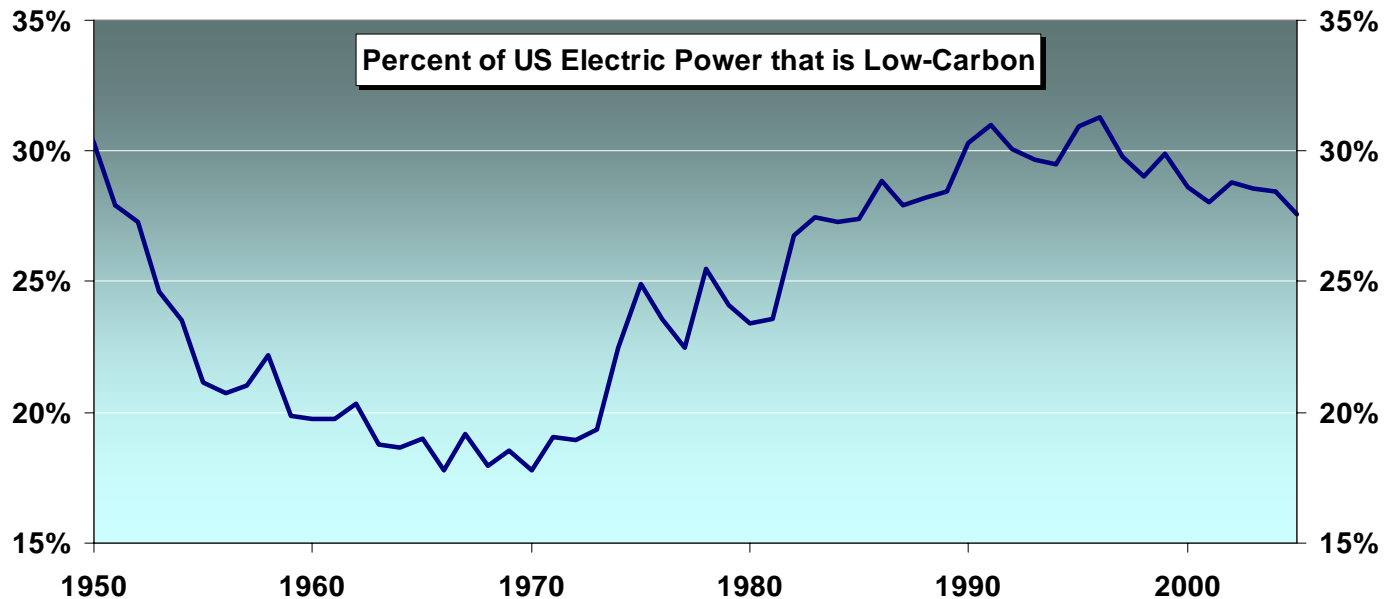
40% Demand Growth by 2025



(or more, with plug-in hybrid electric vehicles)

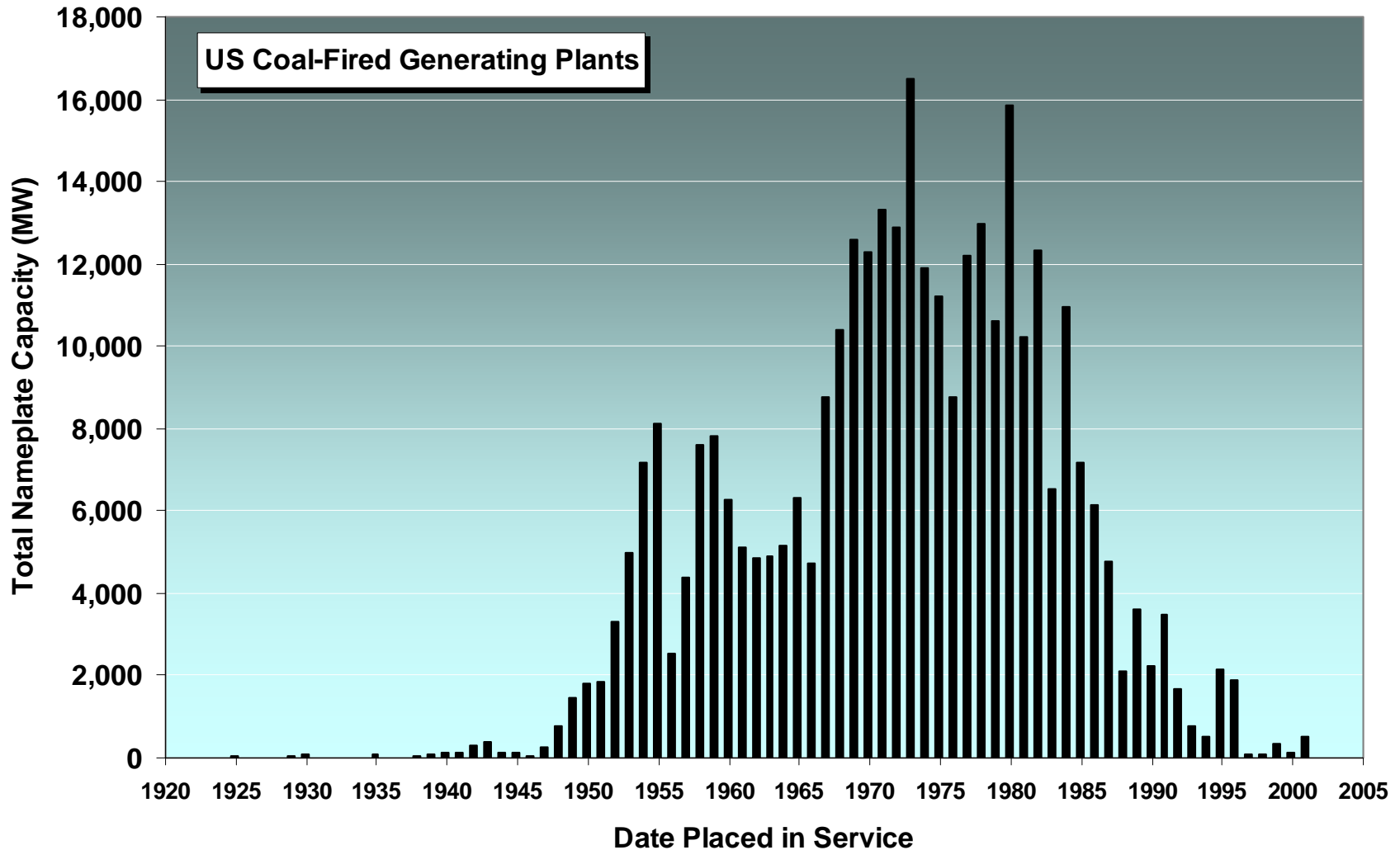
Low-Carbon Electricity Generation Technologies

- Hydroelectric (6½ % of net US generation, but declining)
- Uranium (19% of net US generation, but will decline)
- Biomass, Geothermal, Wind, Solar (1.7%)



- Natural Gas with carbon dioxide capture (amine)
- Coal with carbon dioxide capture (IGCC, oxyfuel, PC+amine)
- Demand reduction (negawatts)

Many coal units will be replaced soon



One Metric is Carbon Mitigation Cost

<u>Technology</u>	<u>Cost / metric ton CO2 avoided</u>
State Conservation Programs (up to 4% of load)	\$5 – \$20
Nuclear (with waste storage cost)	\$5 – \$55
Coal gasification with capture and sequestration	\$15 – \$55
Supercritical pulverized coal with capture and sequestration	\$29 – \$51
Wind power in Texas (with intermittency costs, but without storage)	\$56
Natural gas with capture and sequestration	\$37 – \$74
Geothermal	\$70 – \$100
Direct Capture from the Air	\$80 – \$250
Utility Conservation Programs	\$225 – \$350
Solar in Arizona (without storage or intermittency costs)	\$300 – \$500

Can we afford carbon control for electricity?

**80% reduction at a CO₂ price of \$50 per metric ton:
2.3 ¢/kWh,
or \$90 billion per year,
or 0.75% of GDP.**

**We spent 1.5% of GDP, twice as much, to reduce
air pollution discharges in the 1970's and 1980's.**

[Source: US EPA, *The Benefits and Costs of the Clean Air Act, 1970 to 1990*, chapter 2, Table 1]

Investment decisions in low-carbon generators

- A new pulverized coal plant: 5.1 ¢/kWh
- An IGCC + CCS plant: 7.4 ¢/kWh
- At a 15% discount rate, even a \$100 per ton CO₂ price expected in 2020 has a present value of \$16 per ton, far too low to affect investment.

Investment decisions in low-carbon generators

Our team at CMU has investigated the value of using low-carbon technologies to control SO_2 , NO_x , and Hg, finding that 3P control does not justify such investments if there is no carbon constraint:

Installing a SCR or WFGD on an existing plant, or building a new supercritical coal plant (SCPC) is more profitable than building an IGCC with provision for CCS, or SCPC with provision for CCS.

Similarly, Joule Bergerson and Lester Lave find that

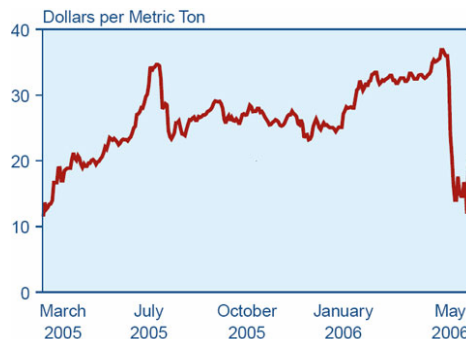
- Tighter SO₂, NO_x, PM and Hg emission standards would not favor a IGCC + CCS system over a PC system.
- If a carbon price were imposed before a coal generation plant were built, the price would have to be at least \$29/ton of CO₂ before the company would decide to add CCS and would choose an IGCC plant.
- A CO₂ price less than \$29/ton would not change the choice of technology: PC without CCS would produce the lowest cost electricity.

Plant-level and societal decision making

- Social discount rates are often lower than corporate discount rates, leading to different decisions.
- If society wants the externalities incorporated soon, so that billions of dollars of plants are not scrapped and charged to customers, it has several options:
 - **Rapid transition to a CO₂ price of \$30-50 per metric ton**
 - **Subsidy**
 - The current production tax credit of 1.9 cents per kWh for wind
 - Federal loan guarantees for nuclear and coal gasification (EPACT05)
 - **Not grandfathering new high-carbon plants**
 - M.G. Morgan (2006). "Don't Grandfather Coal Plants." *Science* **314**(5802): 1049.
 - **Requiring particular technologies by certain dates**

Policy Options

- A renewables portfolio standard
 - Renewables \neq low carbon; inconsistent definitions (biomass, hydro)
 - Many objectives leads to increased costs (e.g. PA solar requirement; low capacity factor (22-39% wind; 11-24% solar) increases cost)
- Carbon tax
 - Unpalatable, especially at levels that would be effective
- Carbon cap and trade
 - Initial allocation issues
 - If allocation is proportional to current emissions, a windfall to those who build new high-carbon generators now.
 - Or, if relatively new plants are exempt, their value will skyrocket.
 - Pressure to inflate initial allocations



EU CO₂ allowance market price

Source: US EIA International Energy Outlook 2006, Fig. 70

A fourth way: A Carbon Portfolio Standard

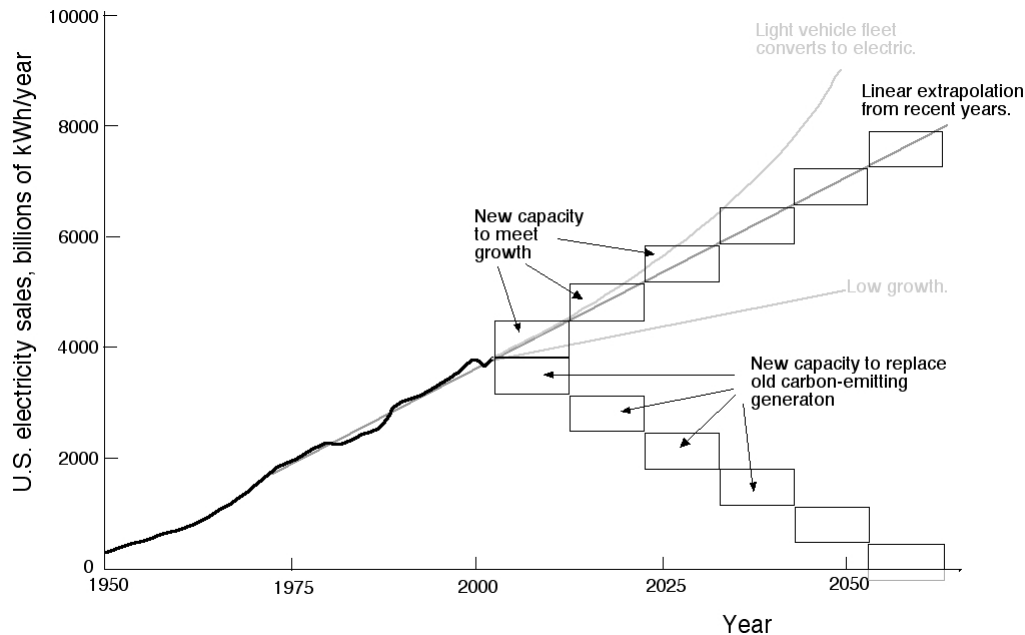
- Electric distributors would be responsible for supplying power with no more than a set number of tons of CO₂.
- Allows state and regional action before federal consensus is reached.
- Can allow trading among jurisdictions with a CPS.
- Avoids the initial allocation mess.
- Does not reward grandfathered plants.
- Aligns societal and firm investment decisions.
- Negawatts directly count.
- Does not pick technology winners.
 - In contrast to some state RPS legislation.
- Can be combined with subsidies and loan guarantees.

Steps towards a CPS

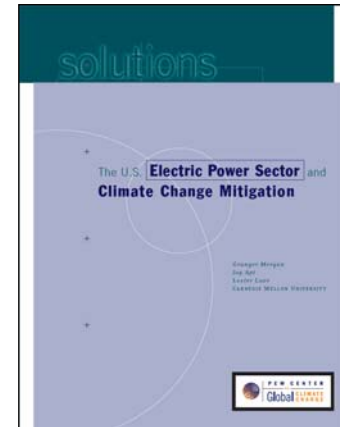
- Richard Cowart proposed a CPS for the New England Regional Greenhouse Gas Initiative (RGGI). Declined.
- California has implemented a hybrid CPS / Cap-and-trade.

Assuming...

...a set of affordable energy technologies with low CO₂ emissions how long would it take to *efficiently* de-carbonize the electricity sector?



For details see the report by Morgan, Apt, and Lave prepared for the Pew Climate Center, "The U.S. Electric Power Sector and Climate Change Mitigation," available at <http://wpweb2k.gsia.cmu.edu/ceic/papers/USElectricPower.pdf>



About 50 years. If we wait a long time and then have to do it quicker, it will be much more expensive because we'll be replacing plants with substantial useful life.

Thank You.

Jay Apt

Department of Engineering & Public Policy and Tepper School of Business

Carnegie Mellon University

Pittsburgh, PA 15213

412-268-3003

apt@cmu.edu