The Government Role in Technology Innovation: Lessons for the Climate Change Policy Agenda

Edward S. Rubin

Carnegie Mellon University
Pittsburgh, Pennsylvania

10th Biennial Conference on Transportation Energy and Environmental Policy:
Toward a Policy Agenda for Climate Change

Asilomar Conference Center, Pacific Grove, California

August 24, 2005

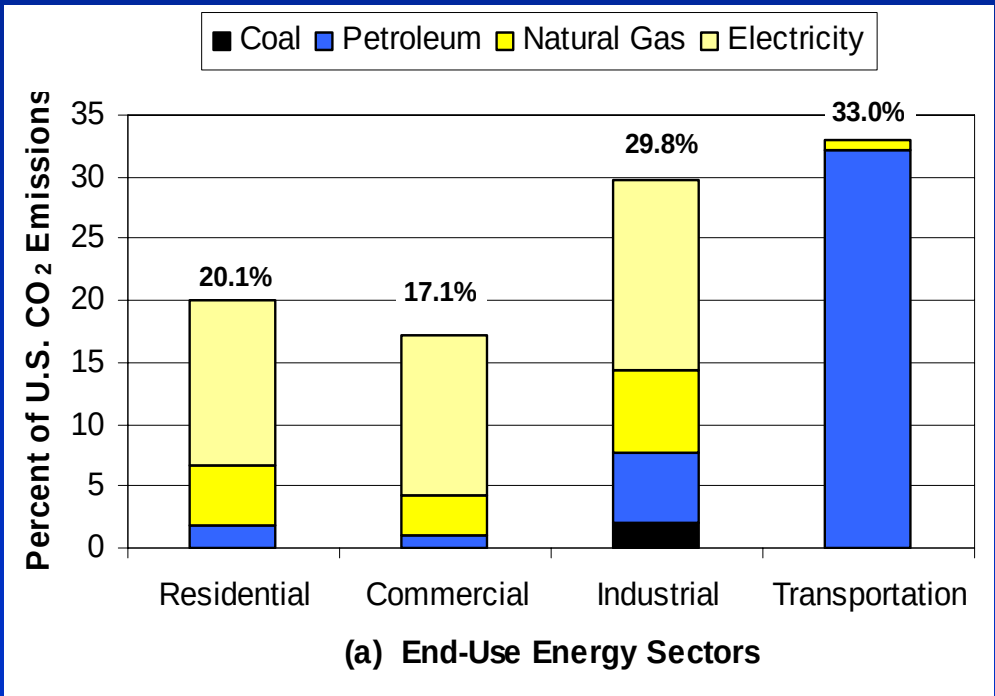
Motivating Questions

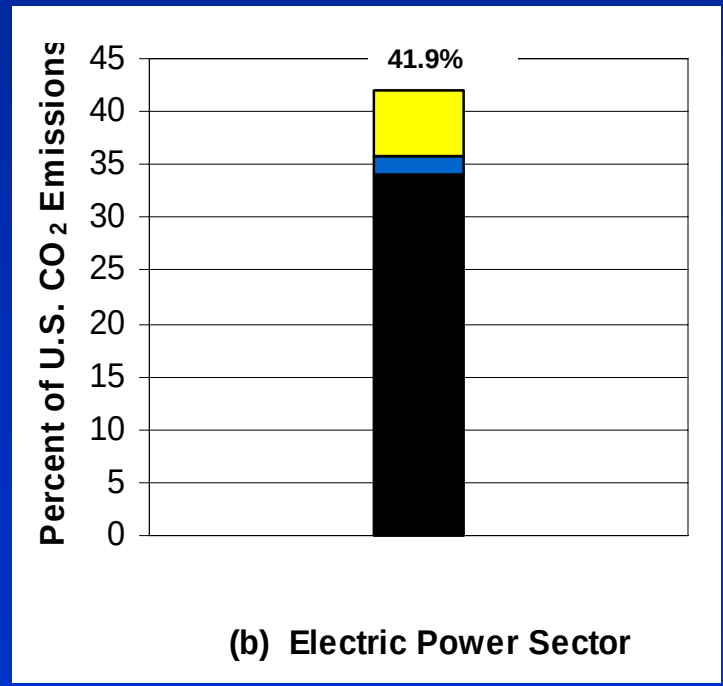
- What kinds of technology innovations are needed to mitigate greenhouse gas emissions?
- What do we know about the process of technology innovation?
- How do government actions influence technology innovation?
- What types of policies are needed to stimulate innovations that mitigate climate change?
- How do technology innovation assumptions affect results of climate policy analysis?

What innovations
are needed to mitigate
greenhouse gas emissions ?

CO_2 Emissions from Energy Use are the Principal Source of GHGs

Current U.S. emissions





Source: Based on USDOE, 2002

Transportation and power generation together account for 75% of current U.S. emissions

Technology Innovations Needed to Mitigate CO_2 Emissions

- More efficient technologies for energy conversion and utilization
- Technologies to produce and utilize alternative energy sources with lower or no GHG emissions
- Technologies for CO_2 capture and storage at large stationary sources
- Technologies that reduce demand for transport and other energy-intensive services

Scale of Deployment Needed

- To achieve significant CO_2 emission reductions, the U.S. alone will have to retrofit or replace:
  - *Hundreds* of power plants
  - *Tens of millions* of automobiles/yr
  - *Hundreds of millions* of other end-use devices

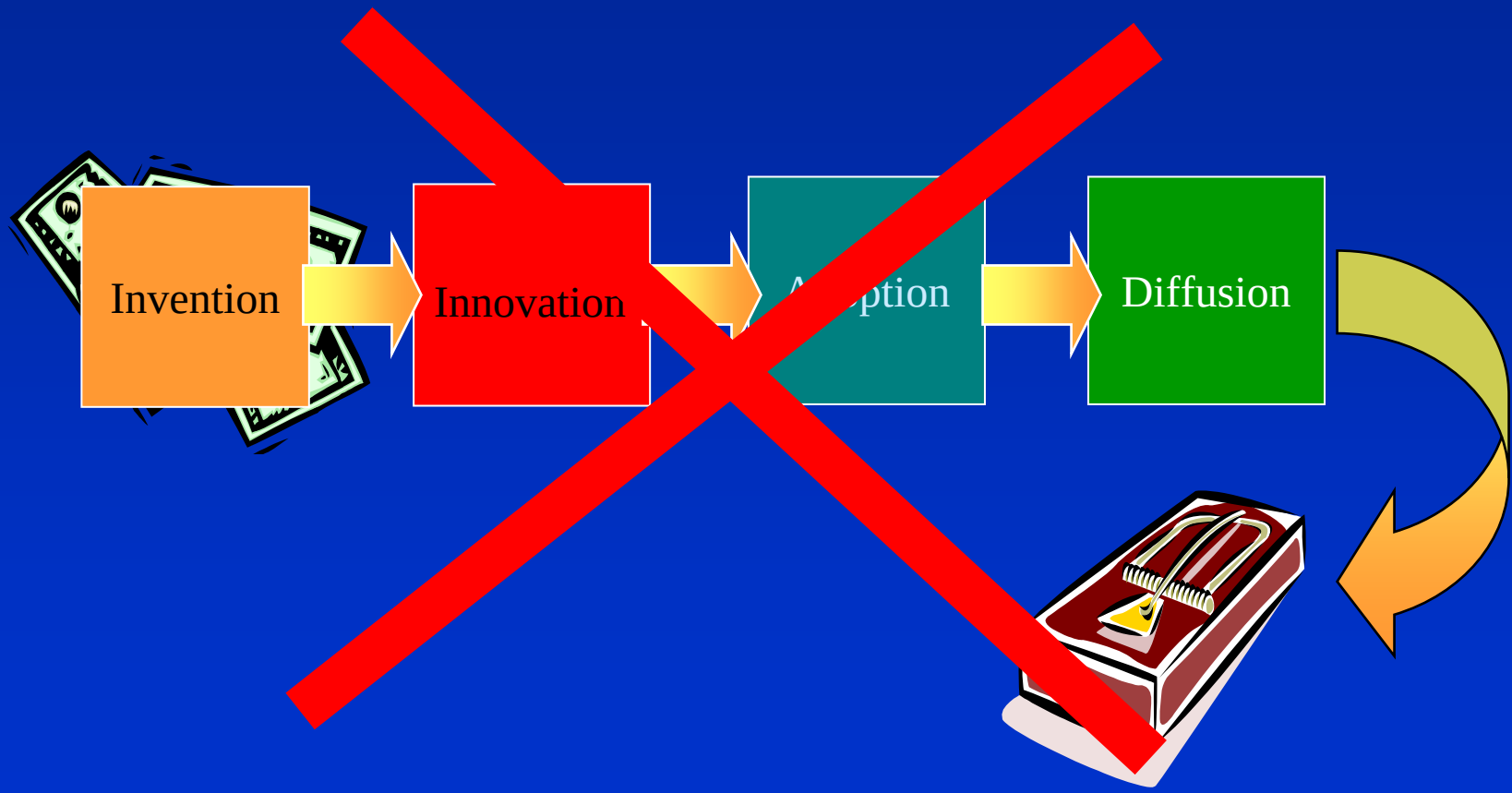
Requires deployment of new technology on a massive scale . . . This won't happen overnight!

What do we know about the process of technology innovation?

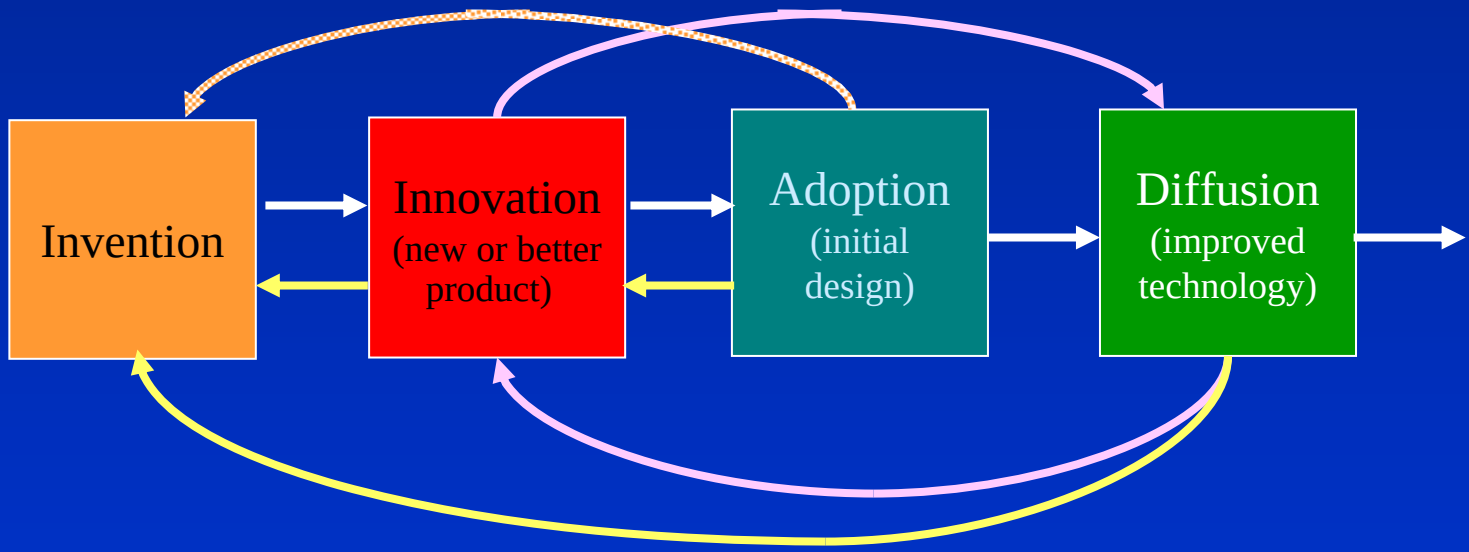
Elements of Technological Change

- Invention
  - Discovery; creation of knowledge; new prototypes
- Innovation
  - Creation of a commercial product or process
- Adoption
  - Deployment and use of the new technology
- Diffusion
  - Increasing adoption and use of the technology

The Linear Model of Technological Change



A More Realistic Model



How do government actions influence technology innovation?

U.S. "Technology Policy" Tools

Direct Government Funding of Research and Development (R&D)

- R&D contracts with private firms
- R&D grants and contracts with universities
- Intramural R&D conducted at gov't laboratories
- R&D contracts with consortia (2 or more of the actors above)

Direct or Indirect Support for Commercialization and Production; Indirect Support for Development

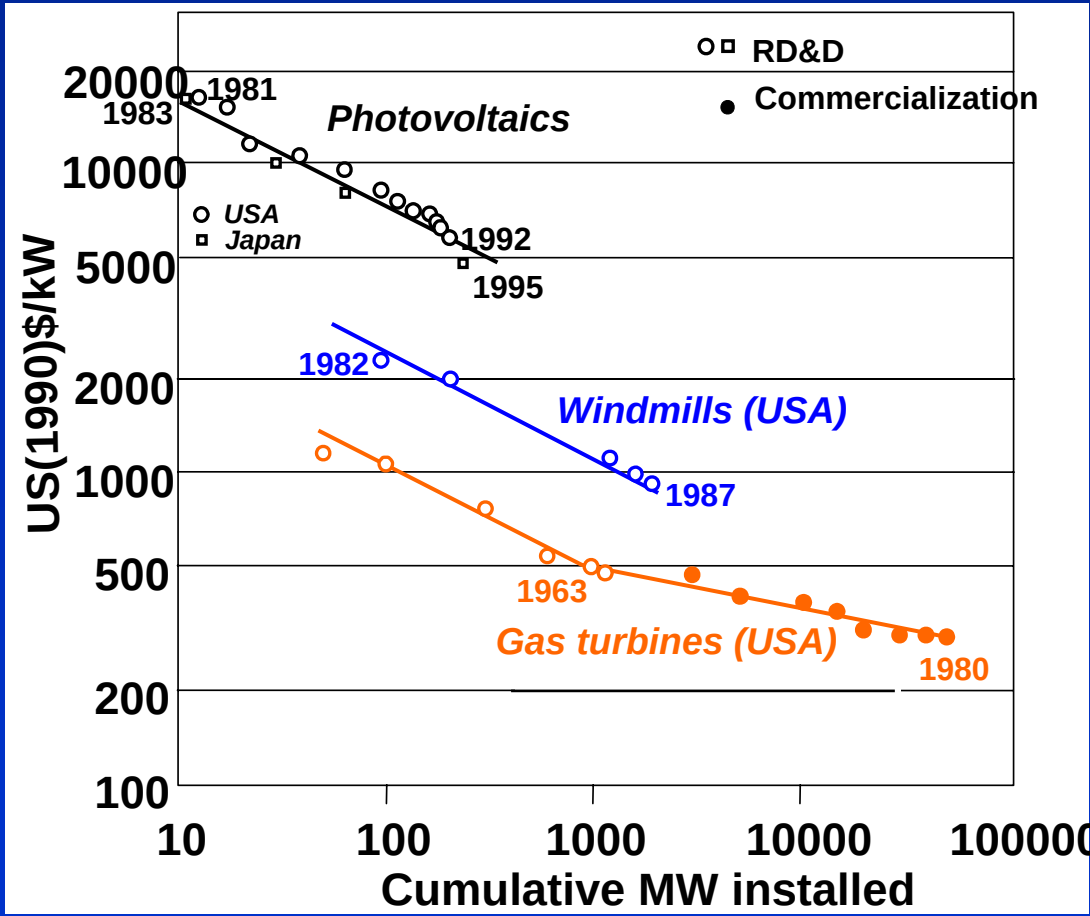
- Patent protection
- R&D tax credits
- Production subsidies or tax credits to firms bringing new technologies to market
- Tax credits or rebates for new technology buyers
- Government procurement
- Demonstration projects

Support for Learning and Diffusion of Knowledge and Technology

- Education and training
- Codification and transfer of knowledge
- Technical standard-setting (non-regulatory)
- Technology and/or industrial extension services
- Publicity and consumer information

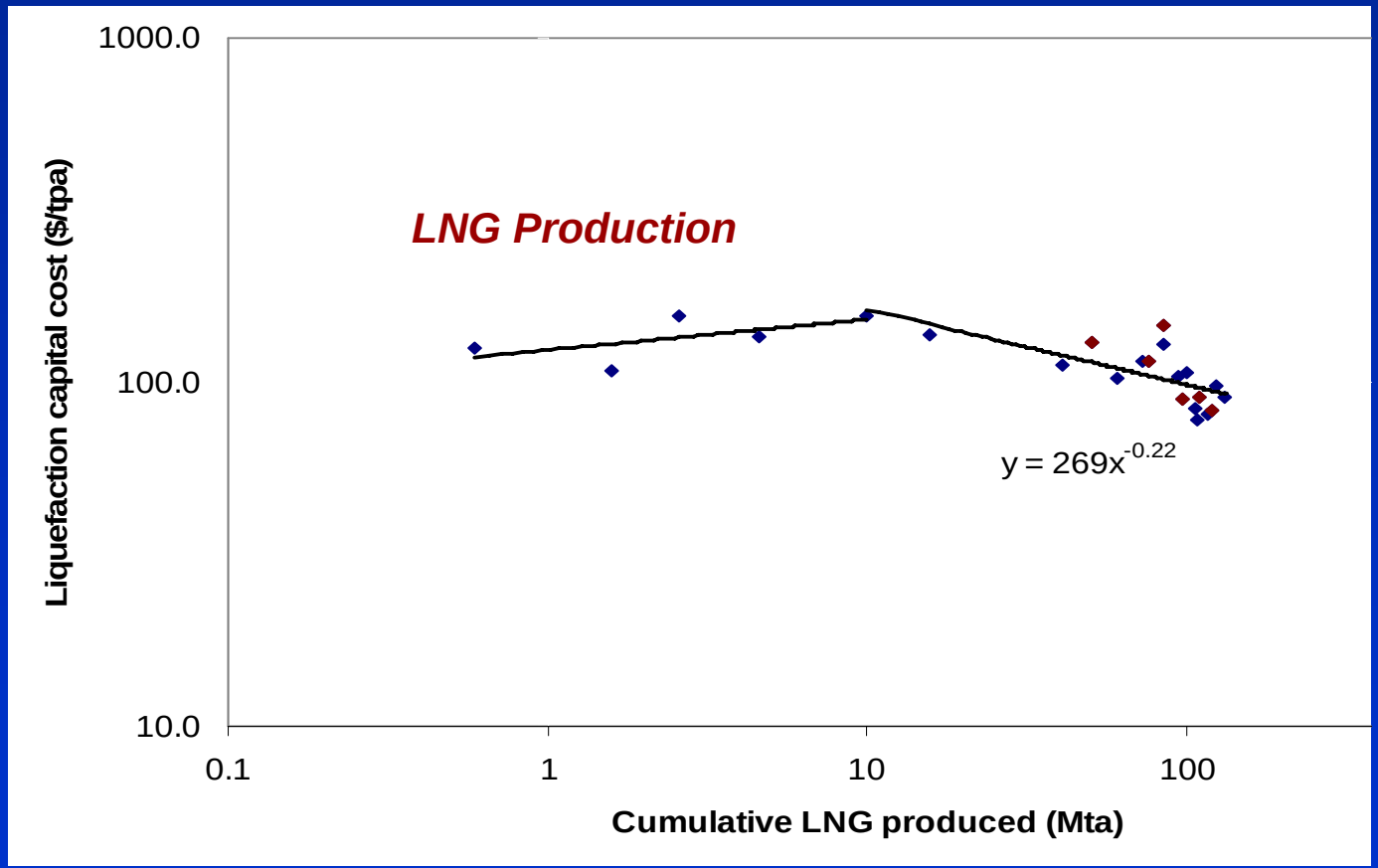
- ***These policies influence different phases of the innovation process***
- ***Provide "carrots" to incentivize technological change & innovation***

Technology Policies Have Reduced the Cost of GHG-Friendly Energy Systems

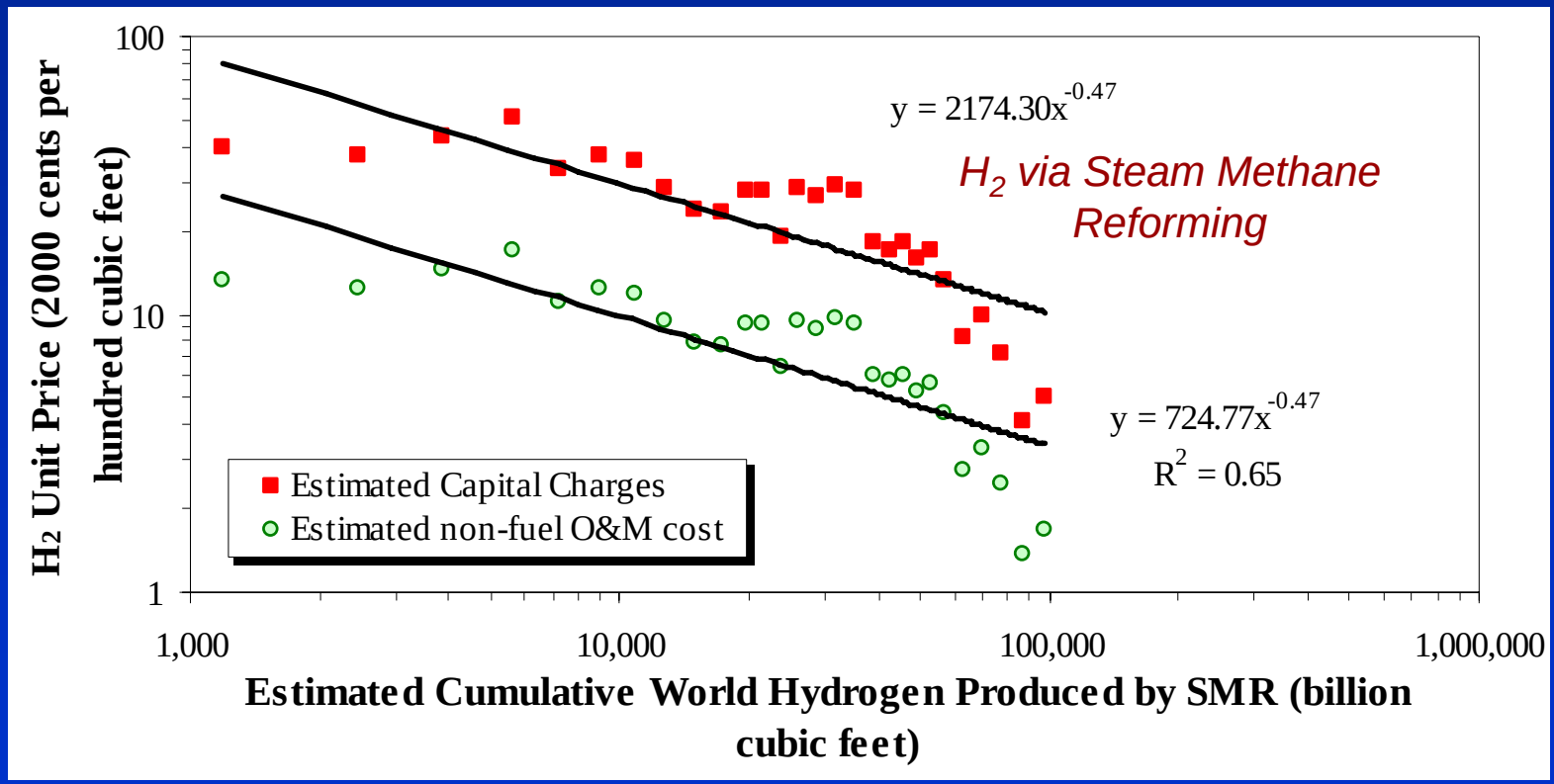


Source: IIASA, 1996

Capital Cost Trend for LNG Production ($/tpa)



Cost Trend for Hydrogen Production via SMR



Lessons Learned from Study of U.S. Technology Policies

- To realize the benefits of technology innovation, a balanced policy portfolio must support not only **R&D**, but also promote **technology deployment** and **diffusion of knowledge**
- Technology innovations cannot be planned or programmed; because outcomes are uncertain, policies should support a **suite of options and approaches** rather than a specific technology or design
- Gov't support for **education and training**, as well as research, enhances the infrastructure necessary to support innovation
- **Competition** among gov't programs (as well as R&D performers) contributes to innovation by encouraging diverse approaches
- Effective policies and programs require **insulation from short-term political pressures** that impede steady progress that is critical to long-term innovations

What types of policies are needed to stimulate innovations that mitigate climate change?

Innovation Policies for Climate Change Mitigation

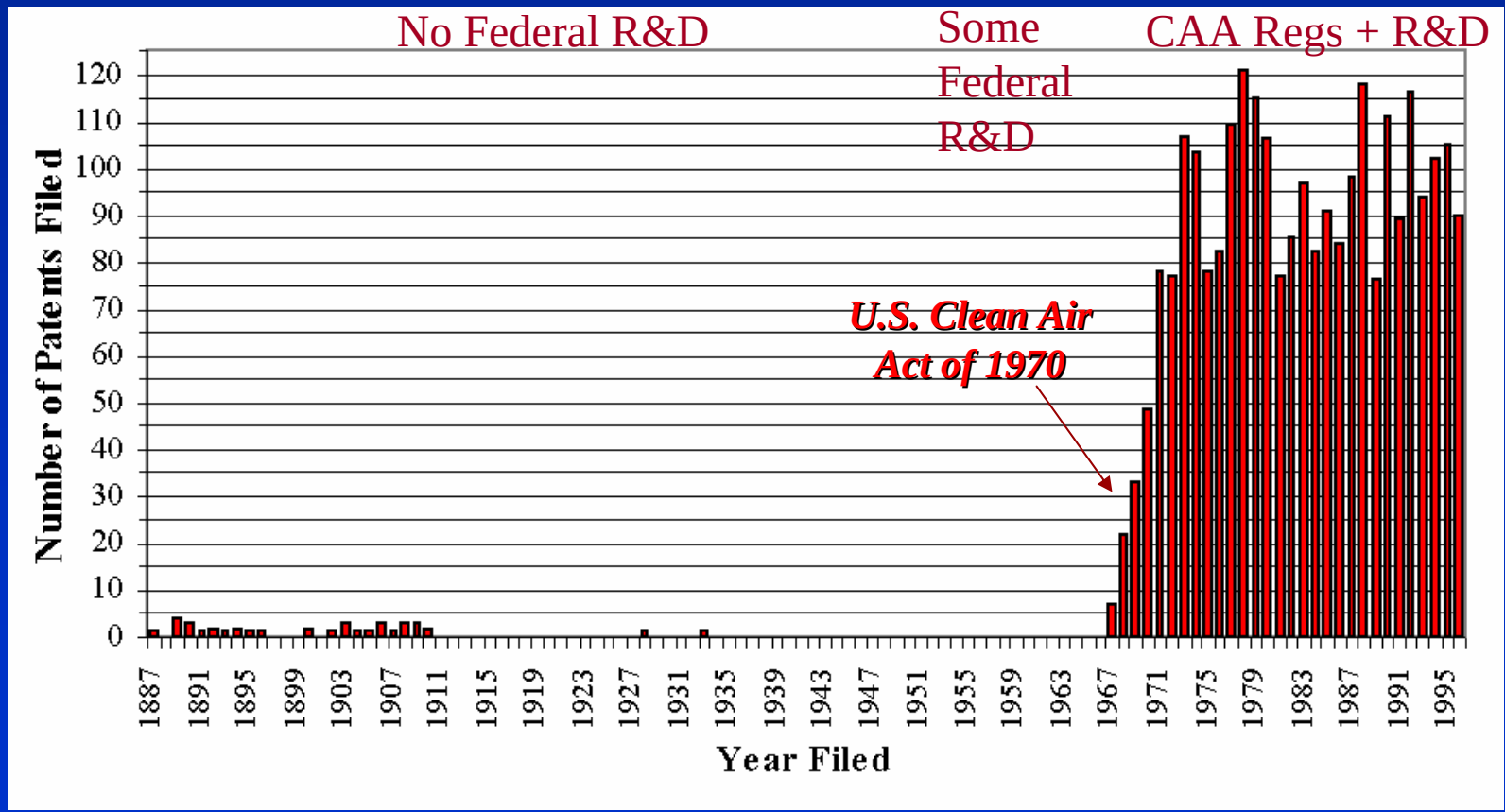
- Global climate change is an *environmental* problem that cannot be addressed by technology policies alone
- *Environmental policies* limiting GHG emissions also are needed to mitigate climate change and achieve international goal of stabilizing GHG concentrations
- *Energy policies* can further help—or impede—progress and innovations that reduce GHG emissions
- A *combination* of regulatory policies and traditional technology policies can most effectively foster innovations favored or required by markets in a carbon-constrained world

Drivers of Environmental Technology Innovation

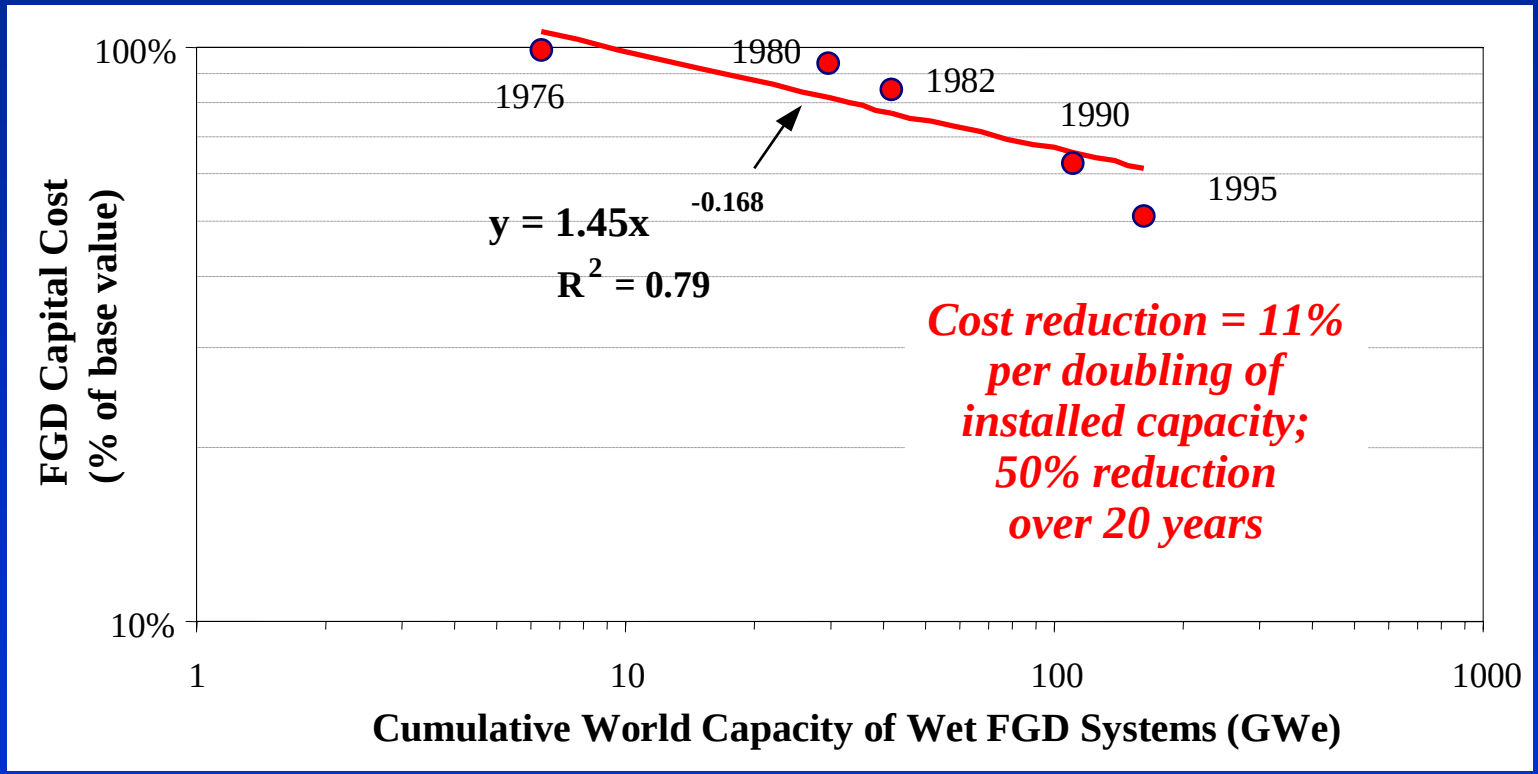
- Most research on innovation has focused on technology policies in a market economy; relatively little study of gov't. role in innovation to achieve environmental goals
- Retrospective case studies can provide useful insights
- At Carnegie Mellon we have conducted case studies of:
  - Power plant air pollution control technologies (SO_2 and NO_x)
  - Automotive air pollution control systems (CO, HC, NO_x)
  - CO_2 capture and storage technologies
  - A variety of energy systems and industrial processes relevant to climate change mitigation

U.S. Patenting Activity in SO_2 Control Technology

(U.S. Patents, Class-based dataset)

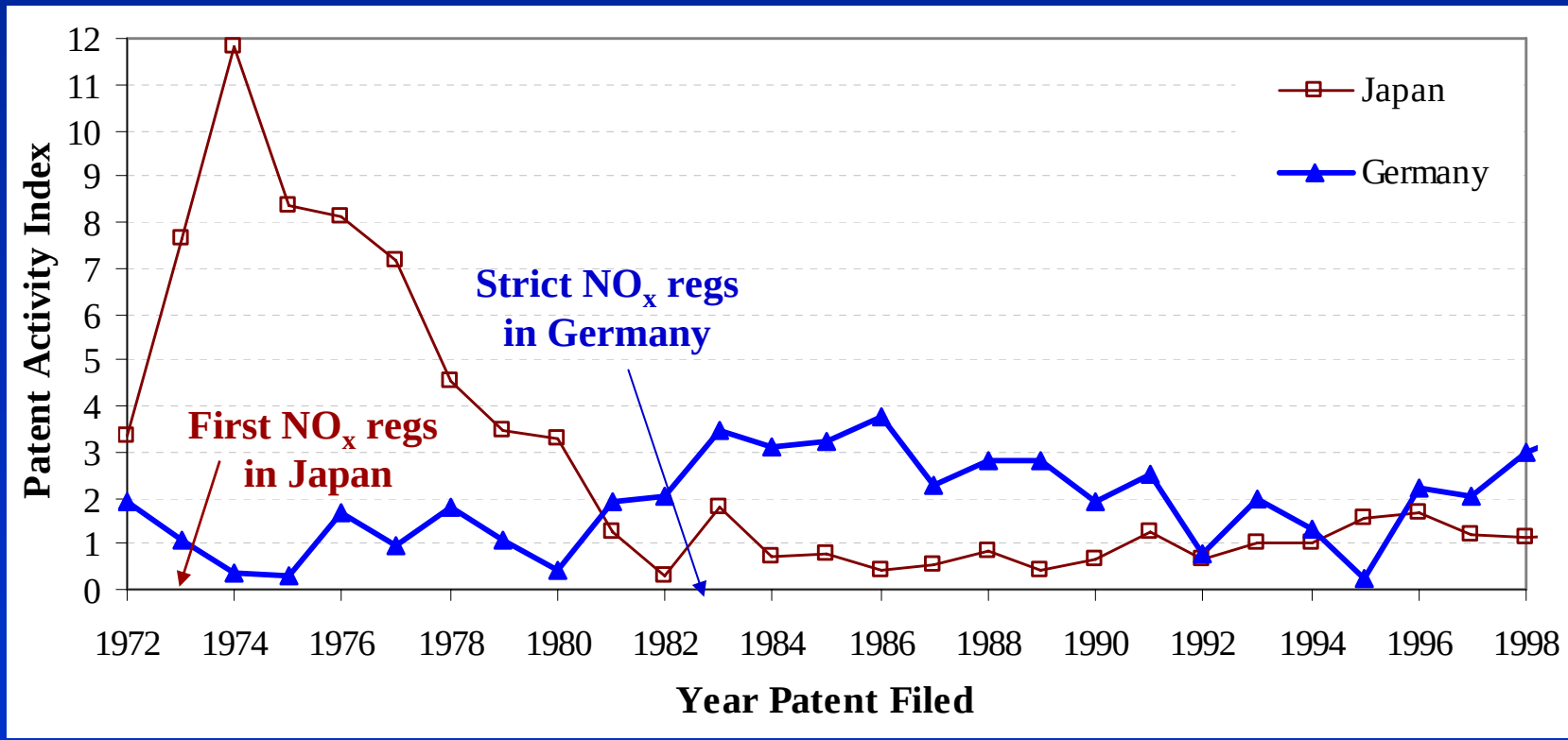


Historical "Learning Curve" for Flue Gas DeSOx Technology

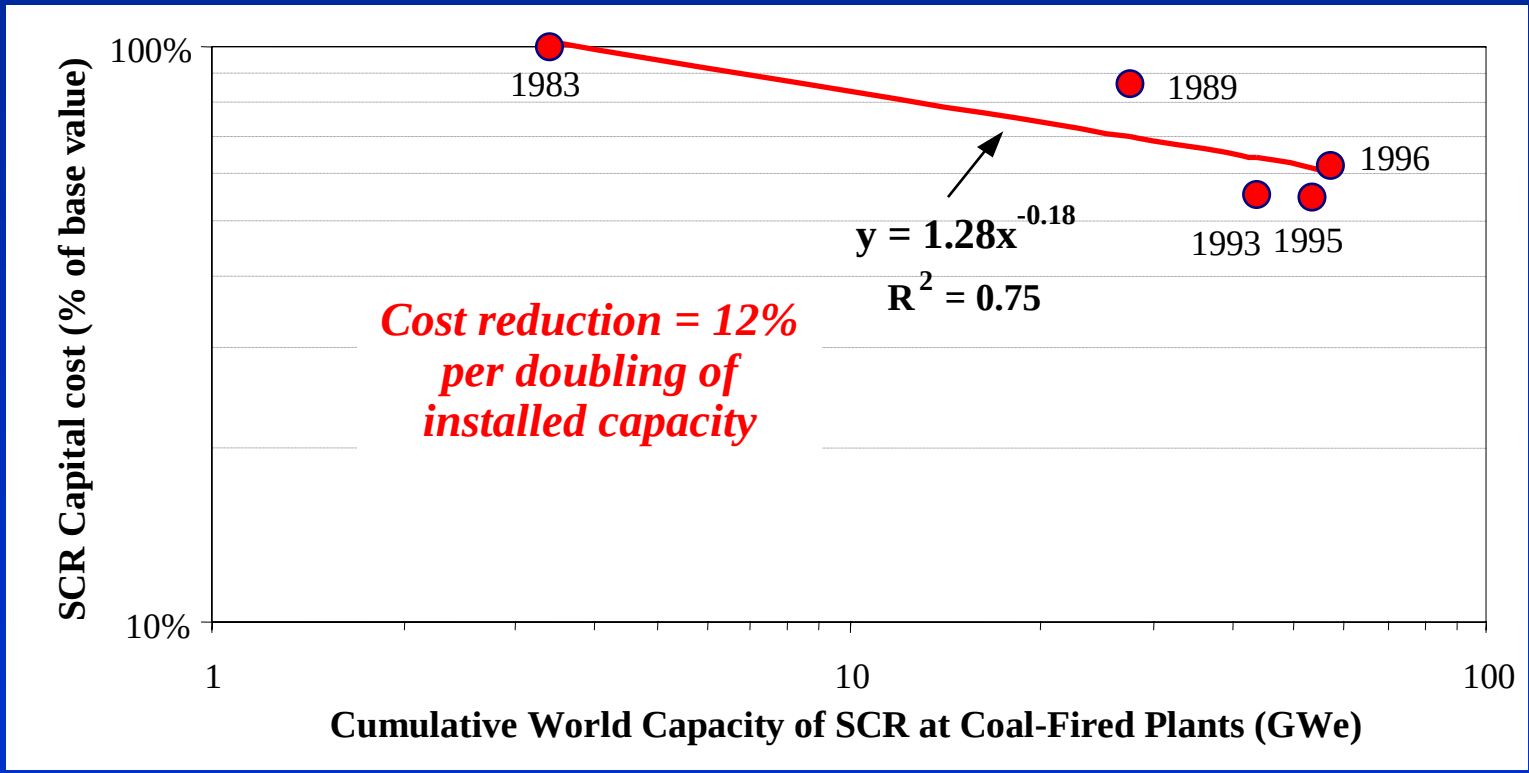


(Based on 90% SO_2 removal, 500 MW plant, 3.5%S coal)

Patenting Activity Index for Flue Gas DeNOx Technology

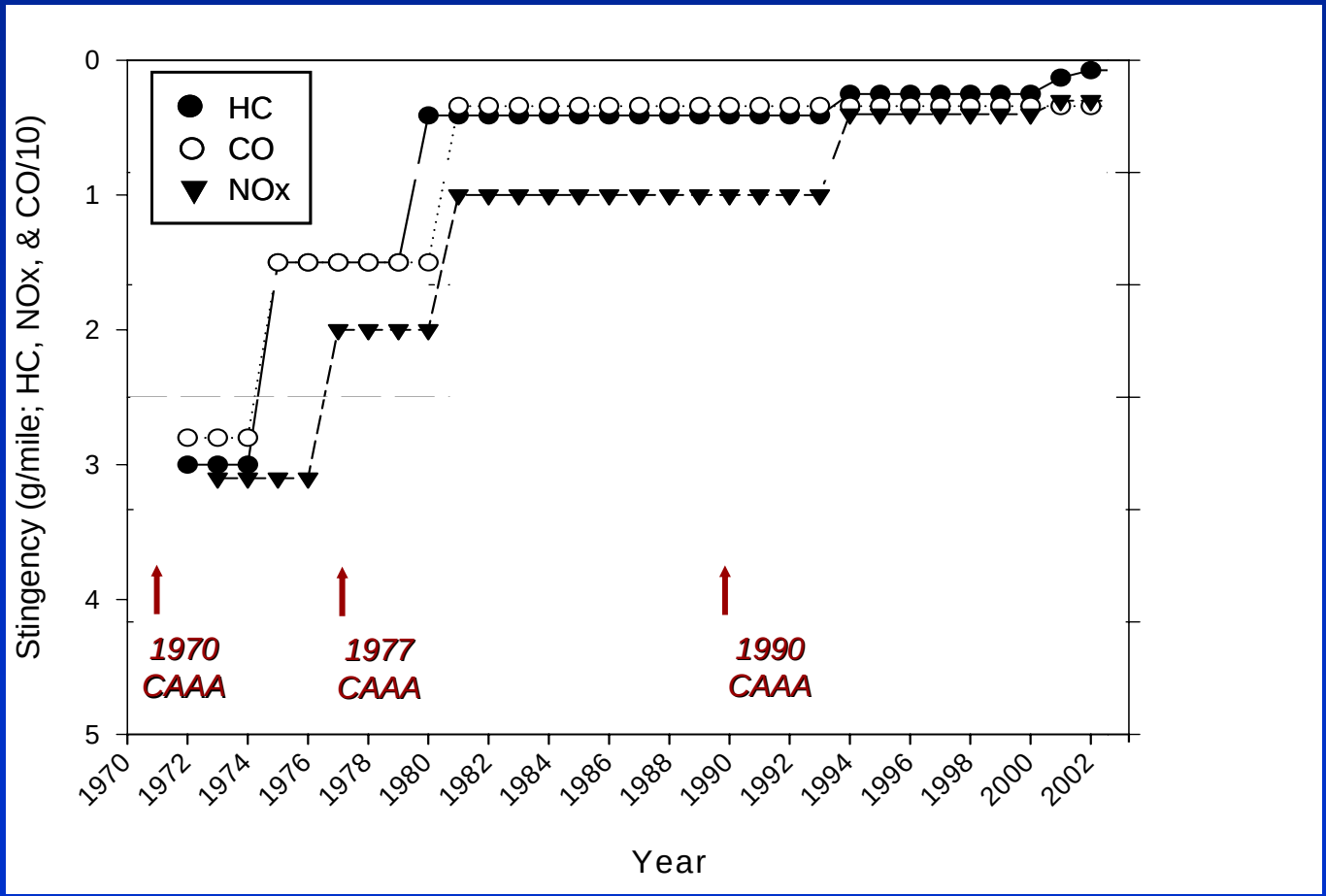


Historical "Learning Curve" for Flue Gas DeNOx Technology

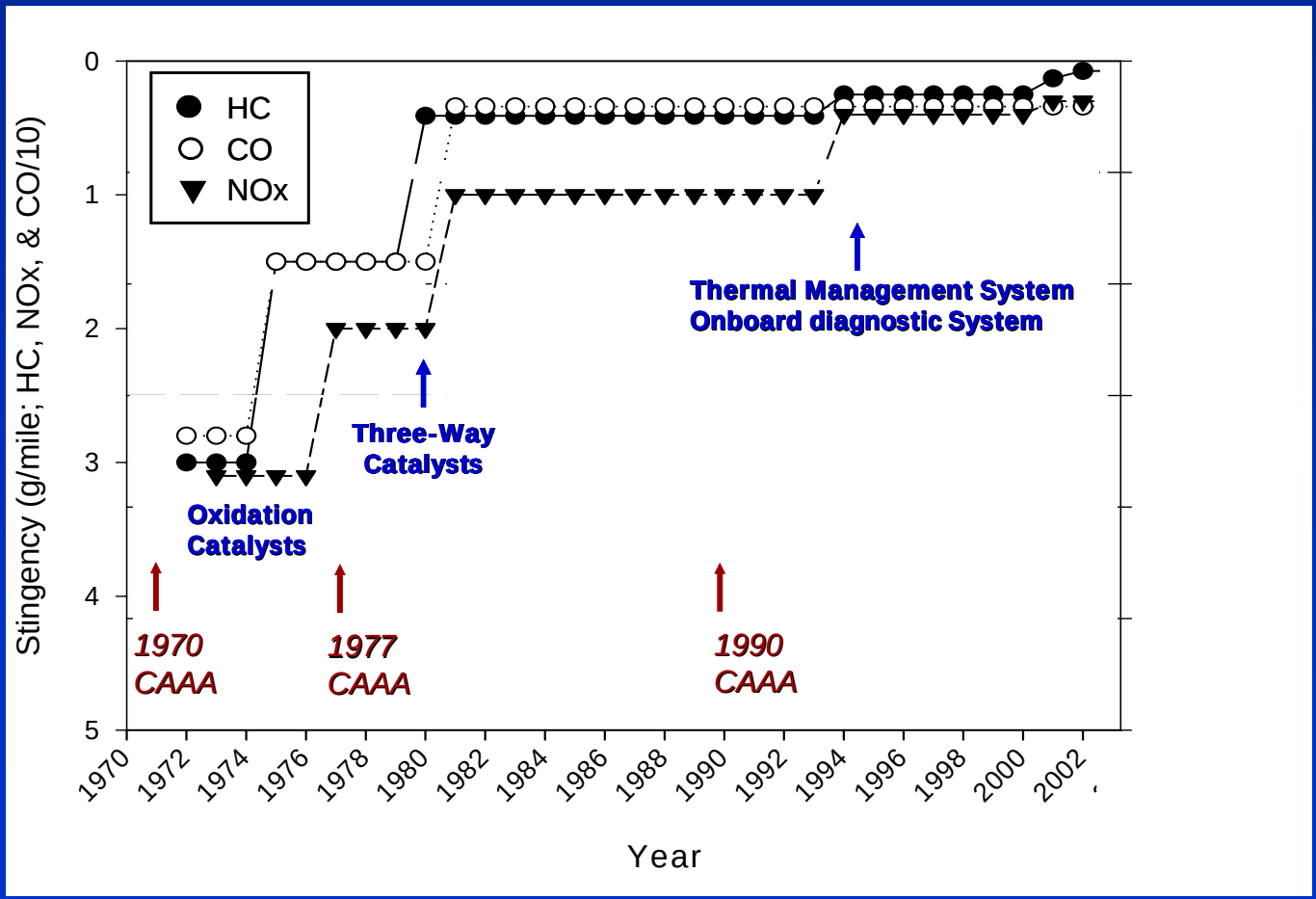


(Based on 80% NO_x removal, 500 MW plant, medium S coal)

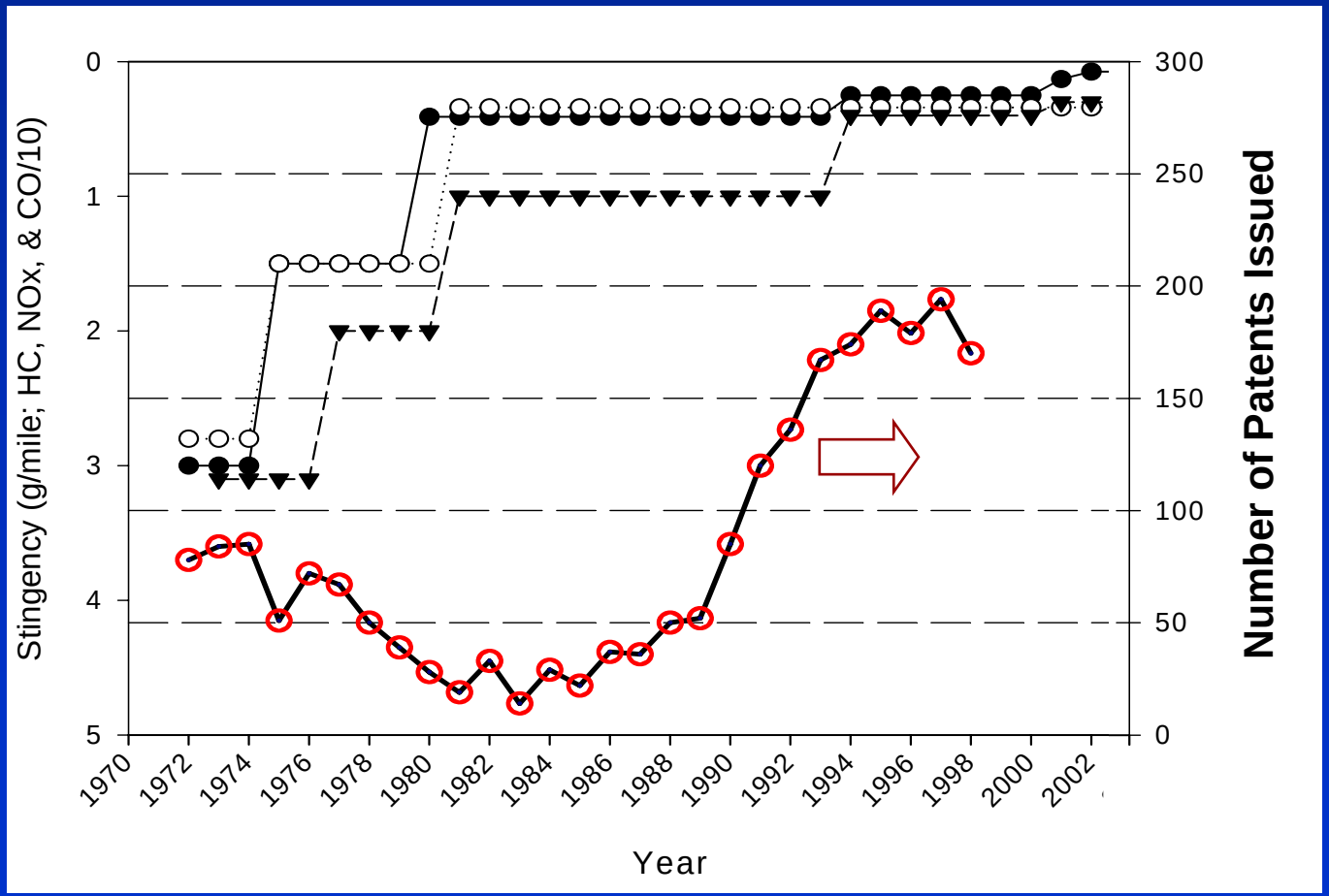
Emission Standards for U.S. Passenger Cars, 1972-2003



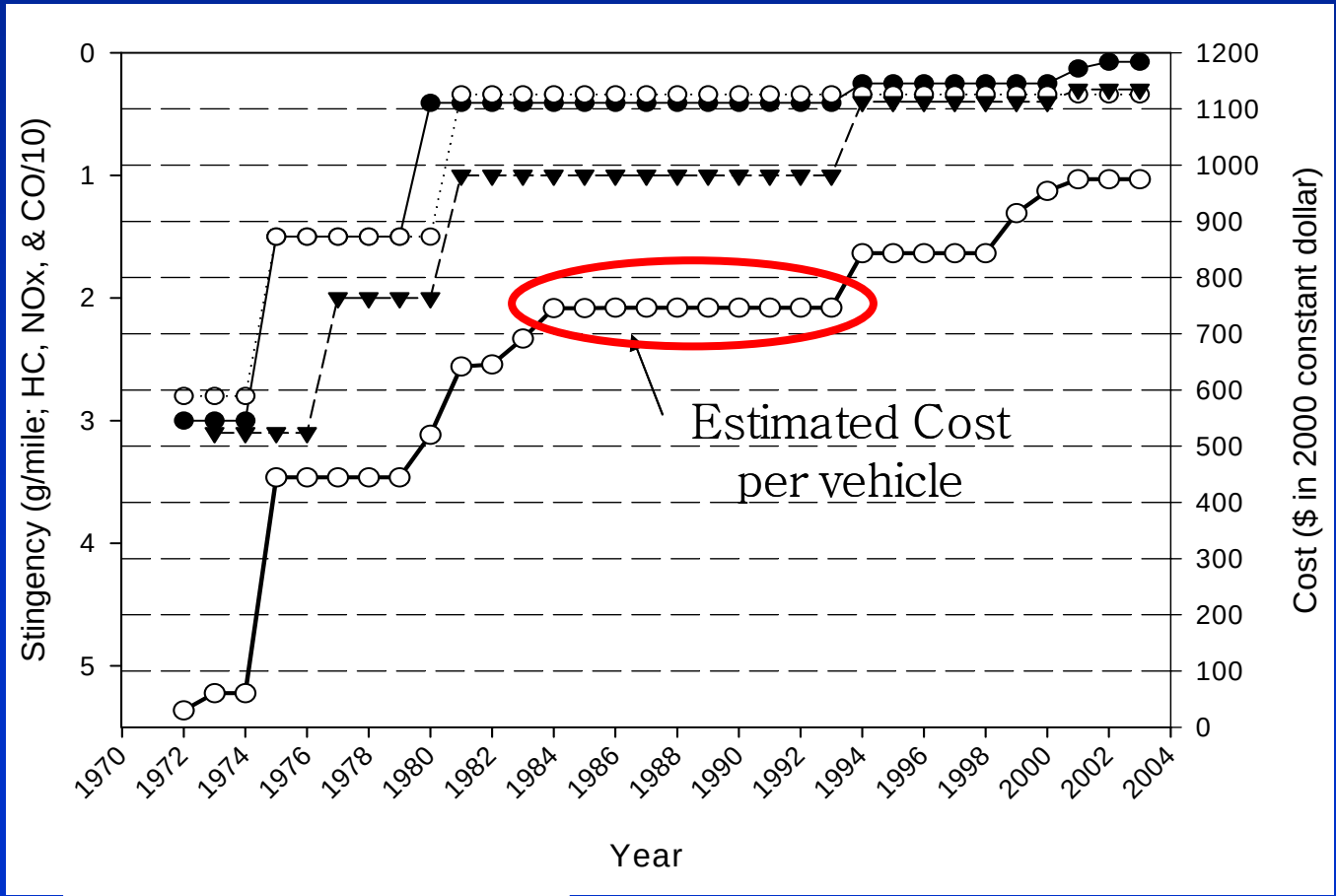
Technological Evolution of Emission Control Systems



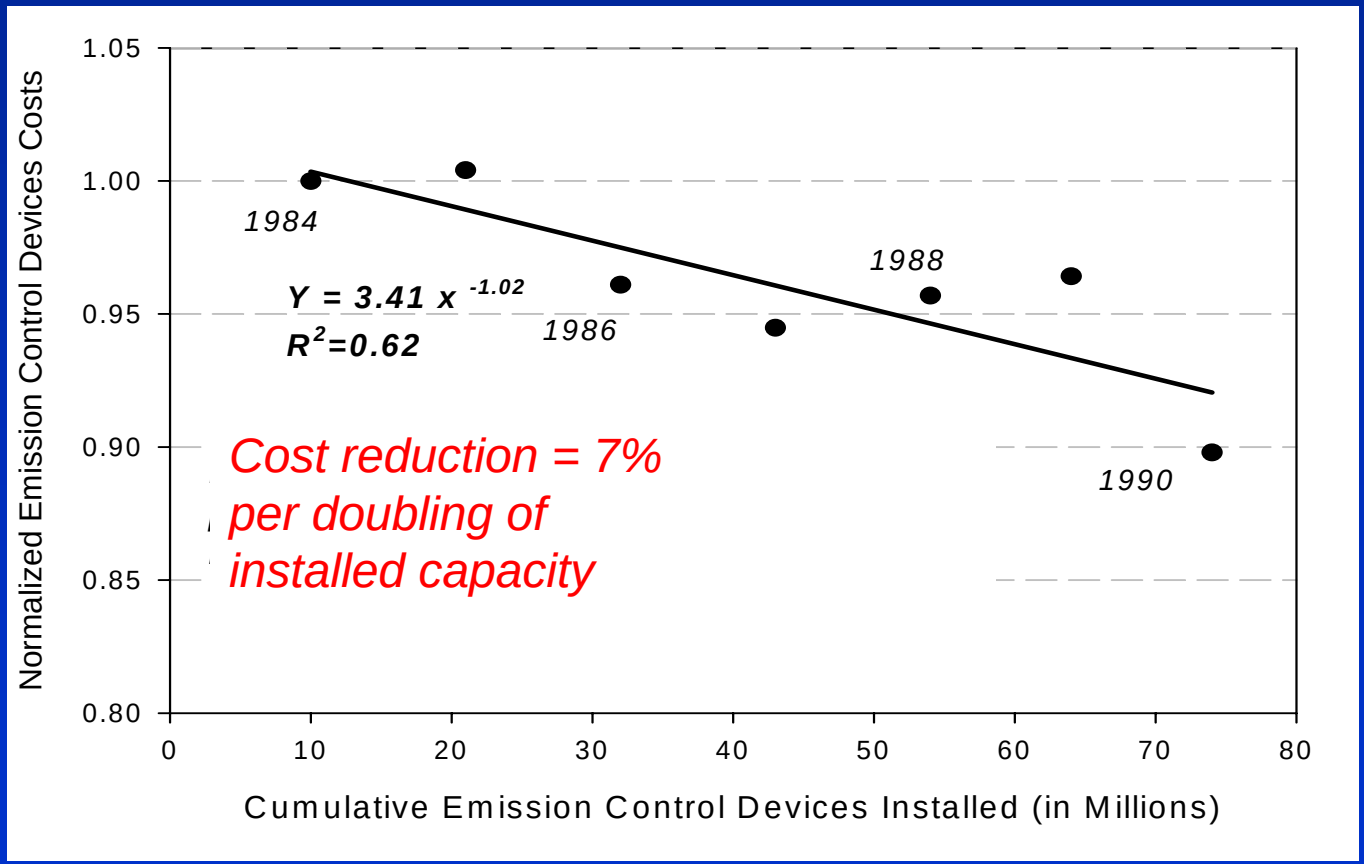
U.S. Patenting Activity in Automotive Emission Controls



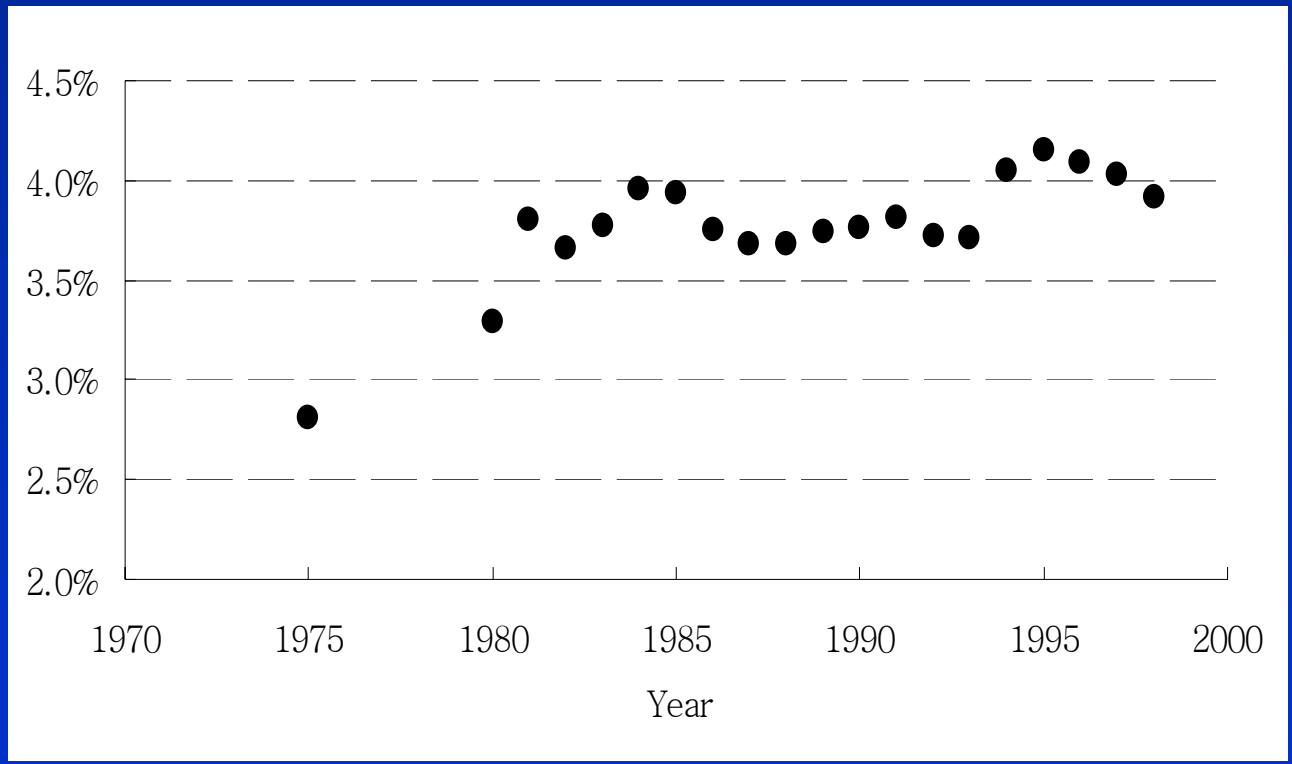
Estimated Cost of Automotive Emission Control System



Estimated Emissions Control Cost Excluding Cost of Precious Metals



Emission Control Cost as Percent of Average Vehicle Cost



Conclusions from Case Studies

- The stringency of emission reduction requirements is a major factor in both *stimulating* and *directing* inventive activities and the deployment of cleaner technologies
- The cost of achieving a given level of emissions reduction tends to fall with increasing deployment and sustained R&D
- Estimated learning rates are similar to those for other consumer technologies in the marketplace
- No strong empirical basis for comparing alternative environmental policy instruments

How do technology innovation assumptions affect results of climate policy analysis?

Conclusions from Modeling Studies

- Assumptions about rates of technological innovation have a significant influence on projected economic impacts, and the outlook for alternative technologies
- The magnitude and timing of these influences depend strongly on the reference case assumptions and the policy scenario considered
- Much more work is needed to better understand and model the key factors that influence technology innovation, especially for environmental technologies