Technology Innovation and Climate Change

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Outline of Talk

- Drivers of climate change
- What action is needed?
- The role of technology innovation
- The role of government policies
- The future outlook

Global climate change

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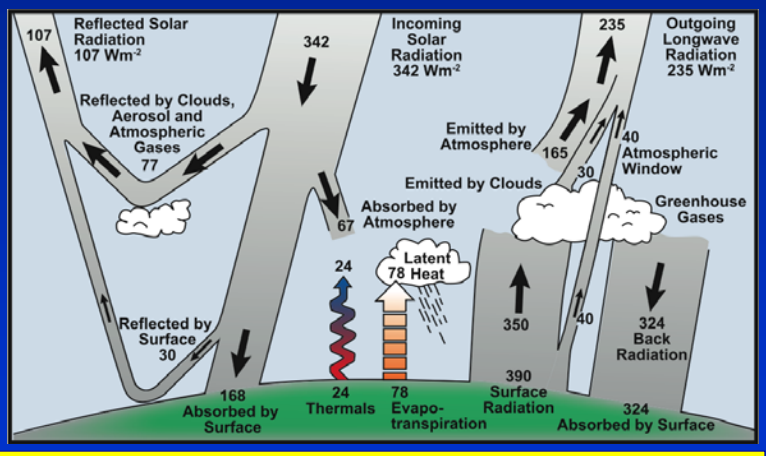
The Global Energy Balance: Average Earth Energy Flows



Source: IPCC, 2007

Without "natural" levels of GHGs (especially H_2O) the average temperature of Earth would be –2°F (instead of 59°F)

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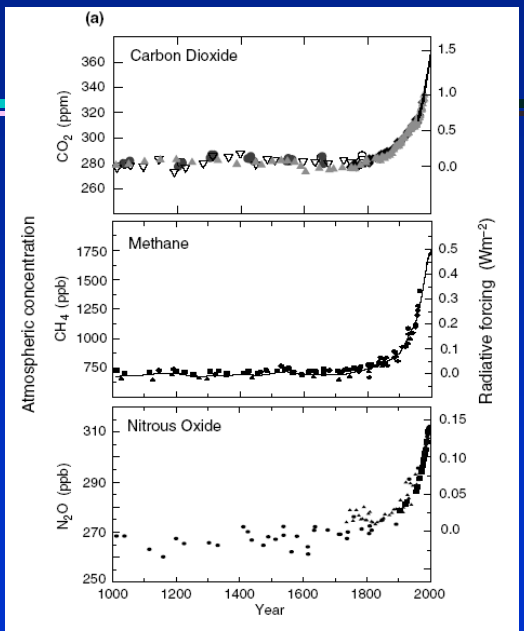
Major Greenhouse Gases that Accumulate in the Atmosphere

Symbol	Name	Common Sources
CO_2	Carbon Dioxide	Fossil fuel combustion, forest clearing, cement production, etc.
CH_4	Methane	Landfills, production and distribution of natural gas & petroleum, fermentation from the digestive system of livestock, rice cultivation, fossil fuel combustion, etc.
N_2O	Nitrous Oxide	Fossil fuel combustion, fertilizers, nylon production, manure, etc.
HFC's	Hydrofluorocarbons	Refrigeration gases, aluminum smelting, semiconductor manufacturing, etc.
PFC's	Perflourocarbons	Aluminum production, semiconductor industry, etc.
SF_6	Sulfur Hexafluoride	Electrical transmissions and distribution systems, circuit breakers, magnesium production, etc.

Unlike "conventional" air pollutants, GHGs—once emitted—are not easily removed. Most remain in the atmosphere for centuries.

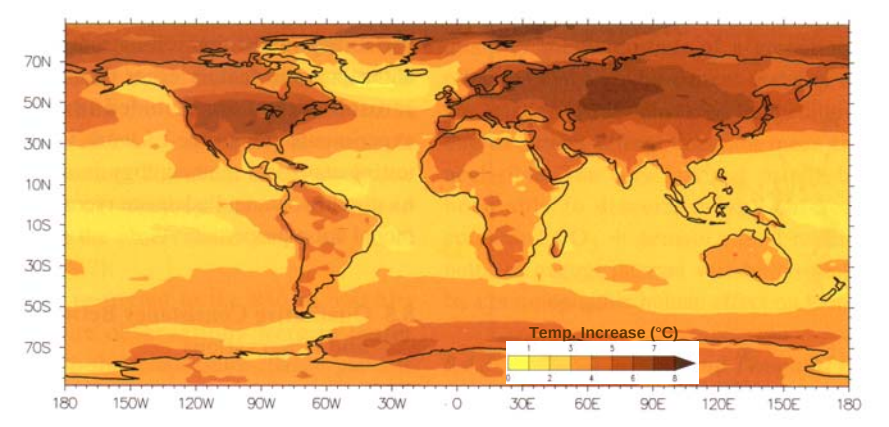
Atmospheric Concentrations

- GHG concentrations in the atmosphere have been increasing steadily as a result of increasing emissions from human activities, especially the burning of fossil fuels



Source: IPCC, 2001

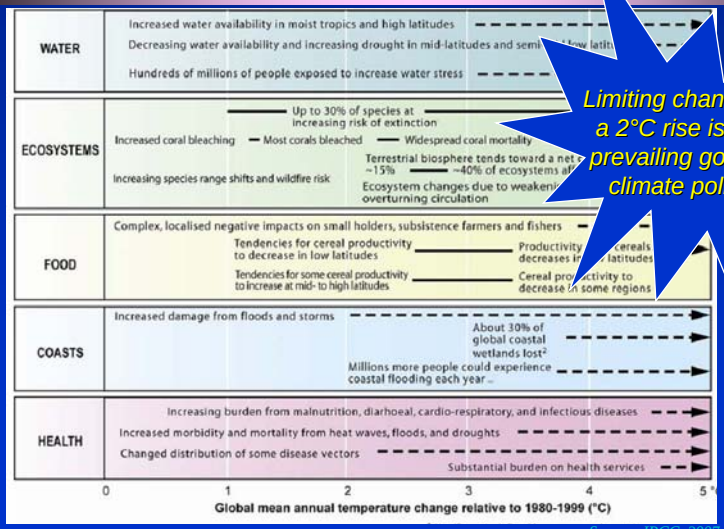
Predicted Temperature Changes for a Doubling of Atmospheric CO_2 Concentration



Source: IPCC

Changes in surface temperature change global air circulation and precipitation patterns, which changes global climate

Climate change impacts for different levels of global warming



Limiting change to a 2°C rise is the prevailing goal of climate policy

Source: IPCC, 2007

What actions are needed?

The Goal of Stabilization

- 1992 U.N. Framework Convention on Climate Change called for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"

**192 countries are parties to the convention*

Implications of Stabilization

- Because of their long atmospheric lifetimes, stabilizing GHG *emissions* is not sufficient to stabilize atmospheric *concentrations*
  - *Analogy: How to stabilize water level in a bathtub with a slow drain?*

- Global emissions must be reduced dramatically in order to stabilize atmospheric GHG concentrations, *no matter what target is selected for stabilization!*

Avoiding Serious Impacts Requires Action Now

The most recent IPCC assessment indicates a need for large reductions by 2050 to avoid serious impacts (*>2ºC rise)*

Required change in global GHG emissions from 2000 to 2050
–85% to –50%

Source: IPCC, 2007

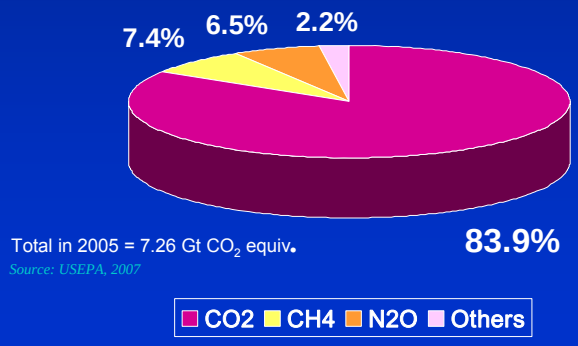
Stabilizing climate change requires urgent action

This conclusion was affirmed in the recent (2010) report of the U.S. National Academies: "America's Climate Choices"

CO_2 from Energy Use is the Dominant Greenhouse Gas

U.S. Greenhouse Gas Emissions

weighted by 100-yr Global Warming Potential (GWP)



Total in 2005 = 7.26 Gt CO_2 equiv.

Source: USEPA, 2007

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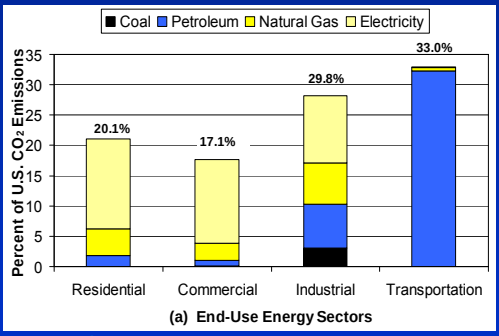
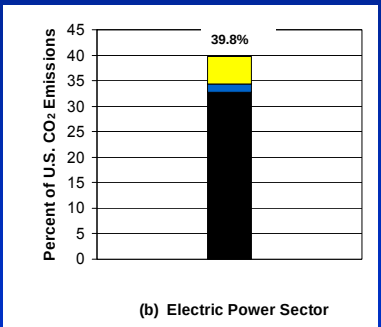
Sources of U.S. CO_2 Emissions

U.S. CO_2 Emissions





Source: Based on USDOE, 2008

Electricity + Vehicles emit ≈ 75% of all CO_2

Fossil fuels = 40% of CO_2 and 70% of U.S. electricity

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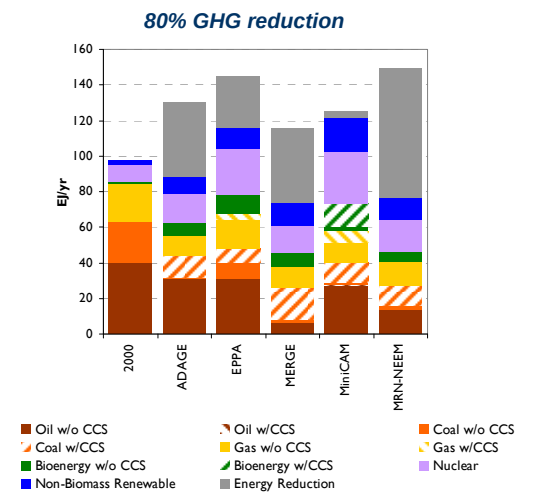
What It Takes to Reach GHG Goals

Least-cost U.S. energy mix in 2050 for a GHG policy scenario (80% below 1990 levels):

Results from energy models show that major changes are needed in the U.S. energy system



Source: EMF22, 2009

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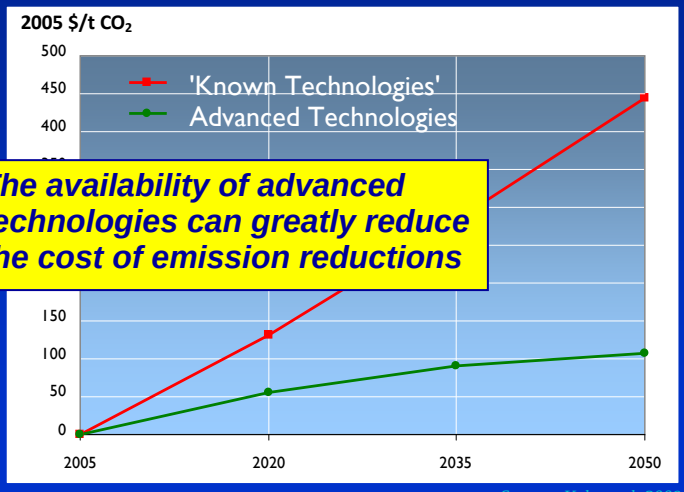
Can We Do This With Current Technology?



The availability of advanced technologies can greatly reduce the cost of emission reductions

Source: Kyle et al. 2009

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The role of technology innovation

Technology Innovation Needs

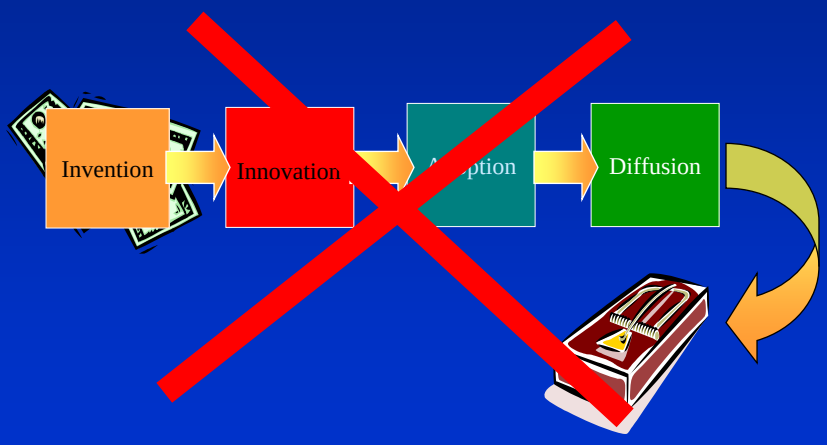
- More efficient technologies for energy utilization and conversion (in all sectors)
- Technologies to produce and utilize alternative energy sources with low or no GHG emissions
- Technologies that can reduce the demands for energy-intensive products and equipment (while providing desired services)

Technological change is required on a very large scale . . . This won't happen overnight !

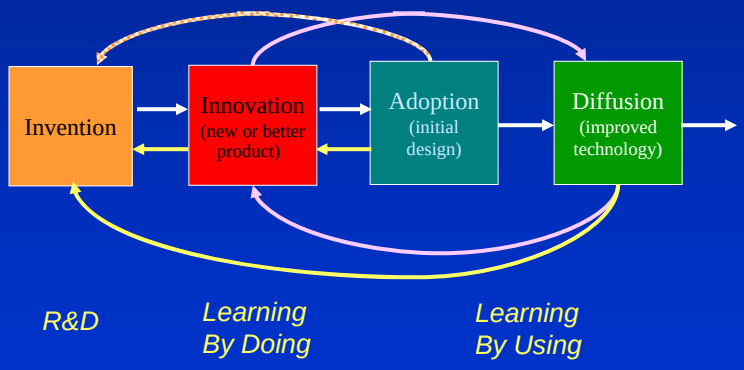
Elements of Technological Change

- 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



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The role of government policies

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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***

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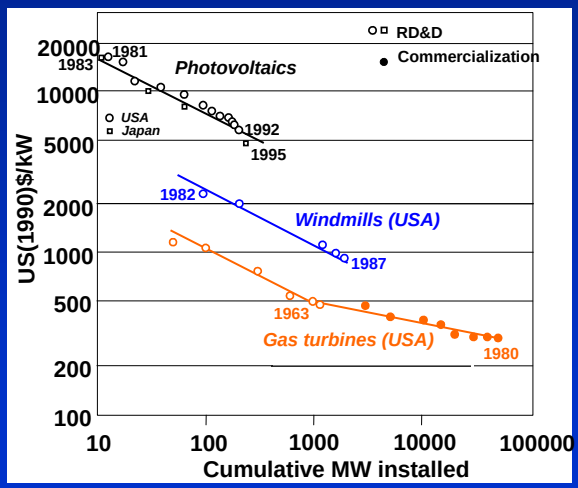
Technology Policies Have Reduced the Cost of GHG-Friendly Energy Systems

Innovations and cost reductions tend to come with increased deployment and use of a new technology, in conjunction with sustained R&D



Source: IIASA, 1996

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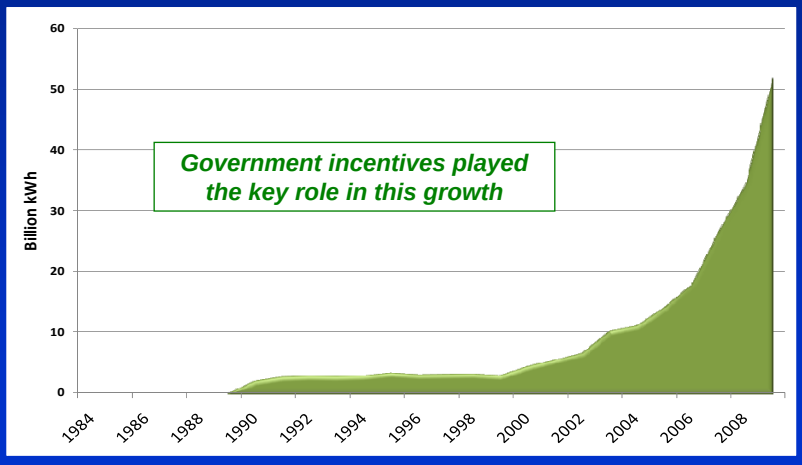
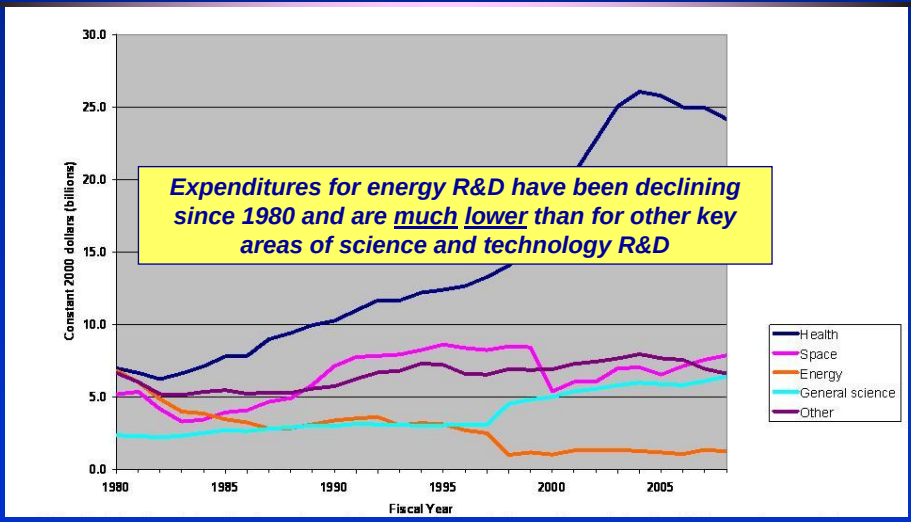
Growth in U.S. Electricity Generation from Wind



Source: EIA, 2010

U.S. Federal R&D Budget Authority for Science and Technology Areas



Source: NSF, 2008; NAS, 2010

U.S. Private-Sector R&D Spending

(Year 2007-08 worldwide amounts for U.S.-based industries w/ >10 firms)

Industry Sector	R&D Investment ($ billion)	% of Sales
All US-based companies (composite)	***209***	***4.5%***
Pharmaceuticals & biotechnology	50	16.7%
Software & computer services	30	10.6%
Oil equipment, services, & distribution	2	2.2%
U.S. electric utilities	~0.5*	0.3%

* Estimate for 1996

Source: NAS, 2010

R&D spending by the U.S. energy sector is far below that of other major industries

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U.S. Regulatory Policy Tools

Economy-wide Measures and/or Sector or Technology-specific Regulations and Standards; e.g.,

- Performance standards (for pollutant emission rates, efficiency, or other measures of performance)
- Portfolio standards
- Cap-and-trade program
- Emissions tax
- Fuels tax

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

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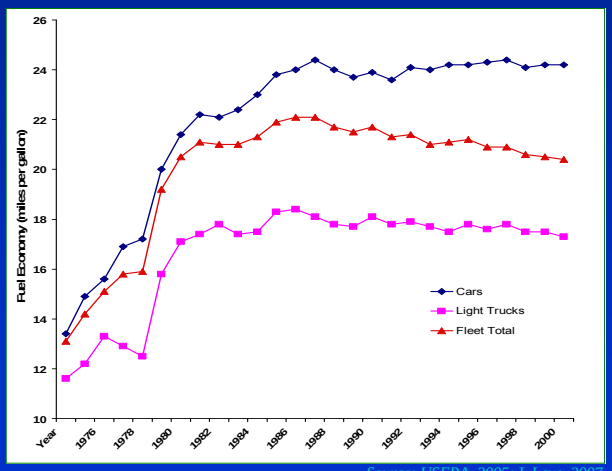
Corporate Average Fuel Economy (CAFE) for New U.S. Vehicles



New CAFE rules will bring fleet average (cars + light trucks) up to 34.1 mpg by 2016

Source: USEPA, 2005; L.Lave, 2007

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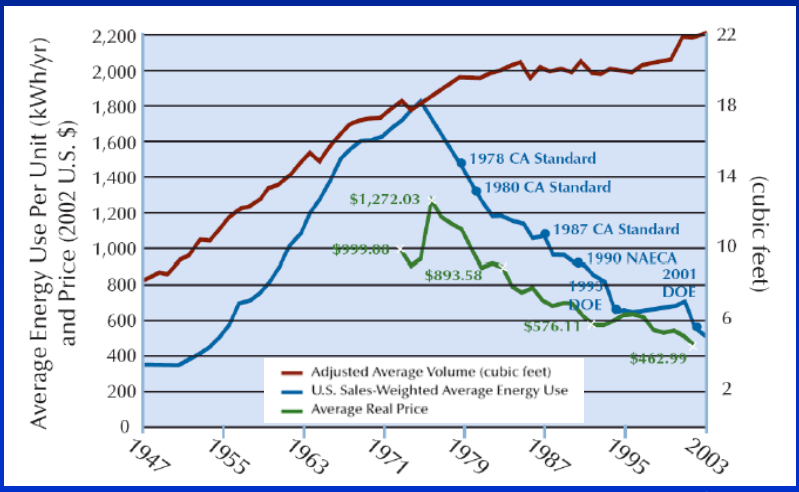
Refrigerator Energy Use in U.S.



Source: A.Rosenfeld, CEC, 2007

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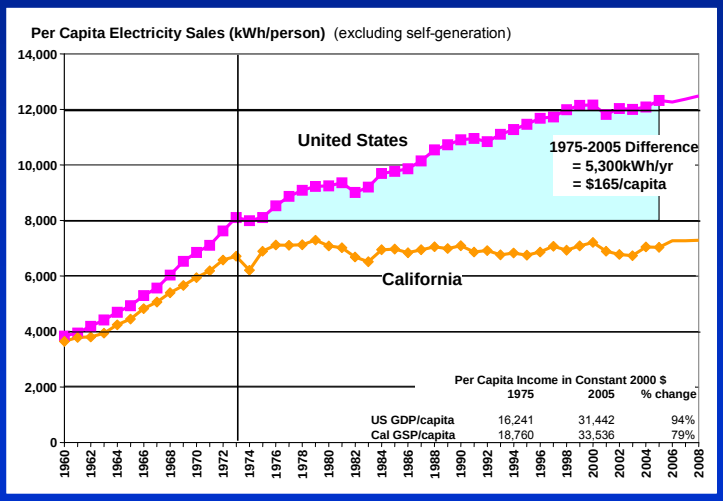
Per Capita Electricity Use:
California vs. U.S. Average



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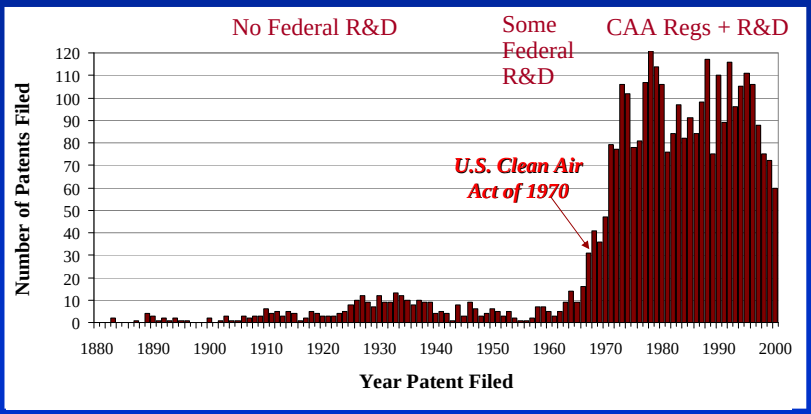
Source: A.Rosenfeld, CEC, 2007

U.S. Patenting Activity in SO_2 Control Technology

Regulatory policies stimulated innovations that reduced emissions



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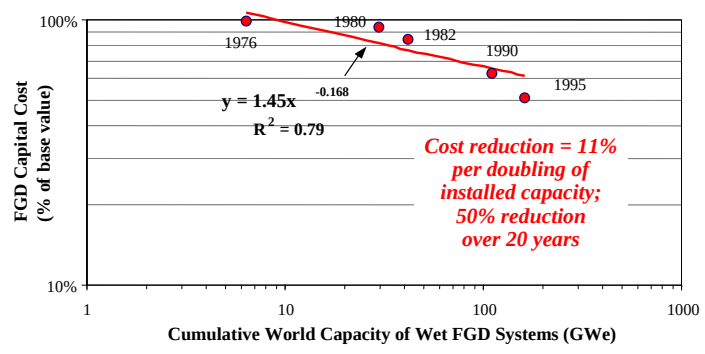
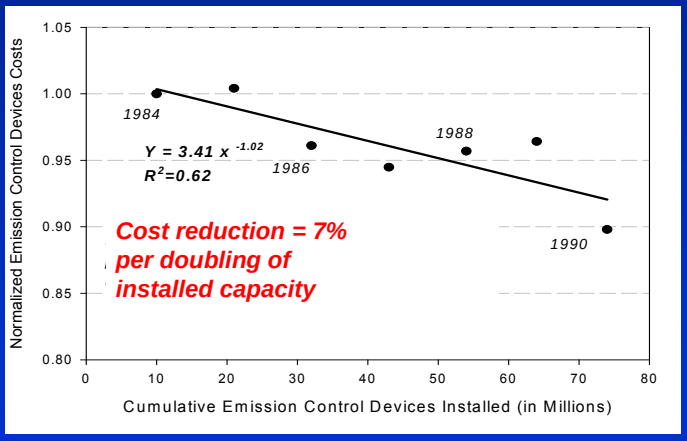
Large declines in cost as emission control systems were deployed

Experience Curve for Flue Gas Desulfurization Systems



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

Automotive Emissions Control Cost
(excluding cost of precious metals)



Source: J. Lee, et al., 2007

Innovation Policies to Mitigate Climate Change

- A *combination* of traditional technology policies and regulatory policies that limit GHG emissions can most effectively foster innovations favored or required in a carbon-constrained world
- Need an adequate "carbon price" (explicit or implicit) to stimulate or create markets for emission reduction measures

The future outlook

Current U.S. Policy

- The Obama Administration goals are to reduce U.S. GHG emissions to:
  - 17% below 2005 levels by 2020
  - 83% below 2005 levels by 2050

but …

- The U.S. Congress has failed to enact climate change legislation needed to achieve significant emission reductions
  - *Many states and regions nonetheless move ahead with their own programs*

Recent EPA Actions

- **GHG Permitting Guidance** (Nov 10, 2010)
  - Discusses options being considered for new or substantially modified CO_2 sources identified under Clean Air Act authority
- **Mandatory GHG Reporting Rule**
  - Subpart PP defines the affected sources (Dec 17, 2010)
  - Other subparts define rules for affected sources (Nov 22, 2010)
- **Underground Injection Control (UIC) Program, Class VI Rule** (Nov 22, 2010)
  - Defines rules and procedures for geological CO_2 sequestration
- Proposed CO_2 Rule under RCRA *(under consideration to clarify the status of captured or injected CO_2)*

So What Will the Future Bring ?

Approach:

Use our Advanced Forecasting Model

Answer:

Wait and find out !

Thank You

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