# CLASS 5 - The Structure of an Energy Technology Revolution

## IAP Course: Fundamentals of Science and Technology Public Policymaking

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# To Recap the data: Decline in Energy R&D

- US federal spending on R&D for new energy tech is about half what it was in 1980
  - Energy declined from 10% of all US R&D in 1980 to just 2% in 2005. (in '02 dollars)
  - Between 1980 and 2005, the US decreased its energy R&D investment by 58%.
  - Federal Energy R&D spending level in '07 is less than half the R&D spending of the largest US pharmaceutical company.
- Private sector R&D story is similar.

# US Public and Private Trends in Energy R&D

Source: in Nemet and Kammen (2007)

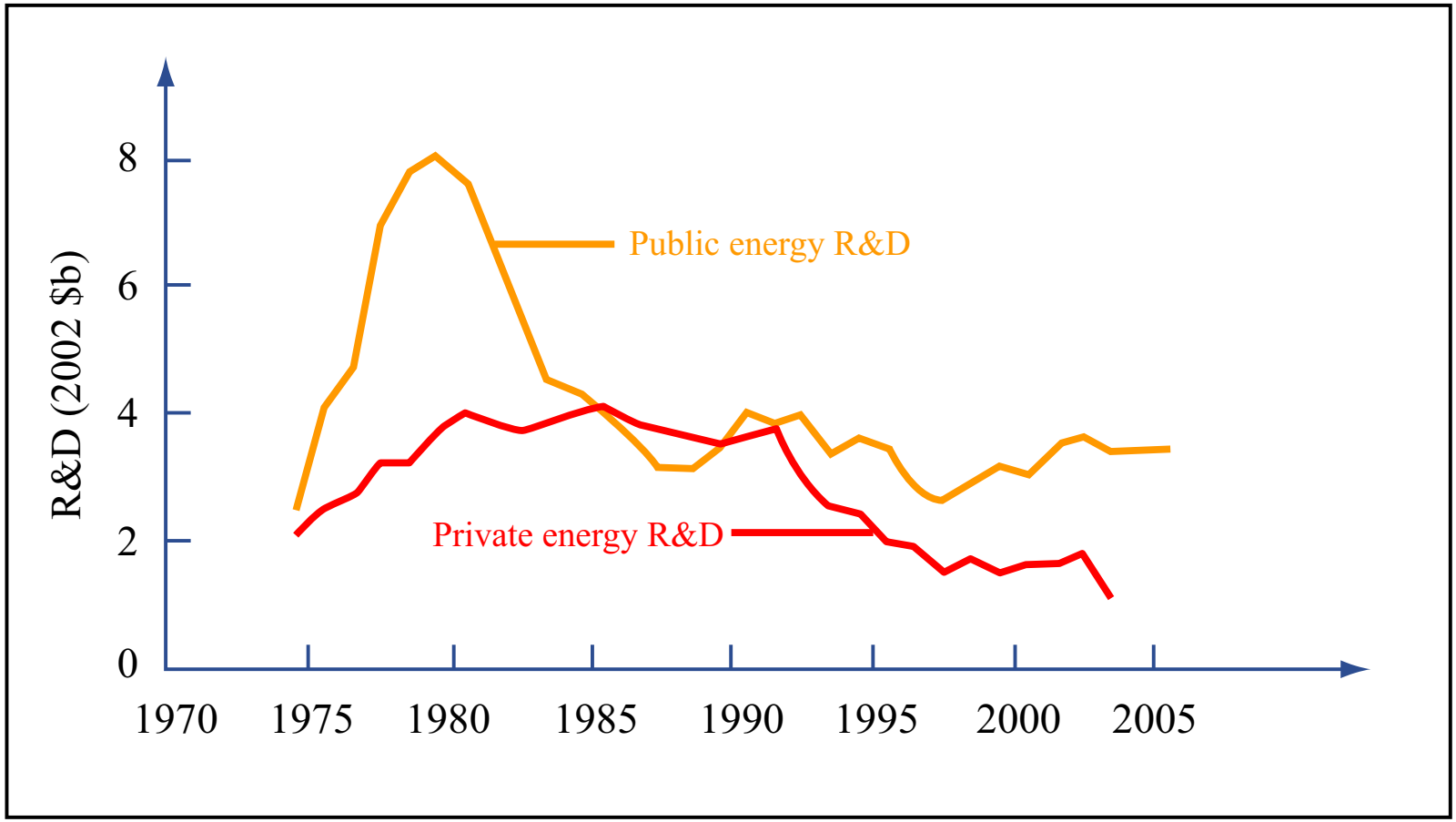



Figure by MIT OpenCourseWare.

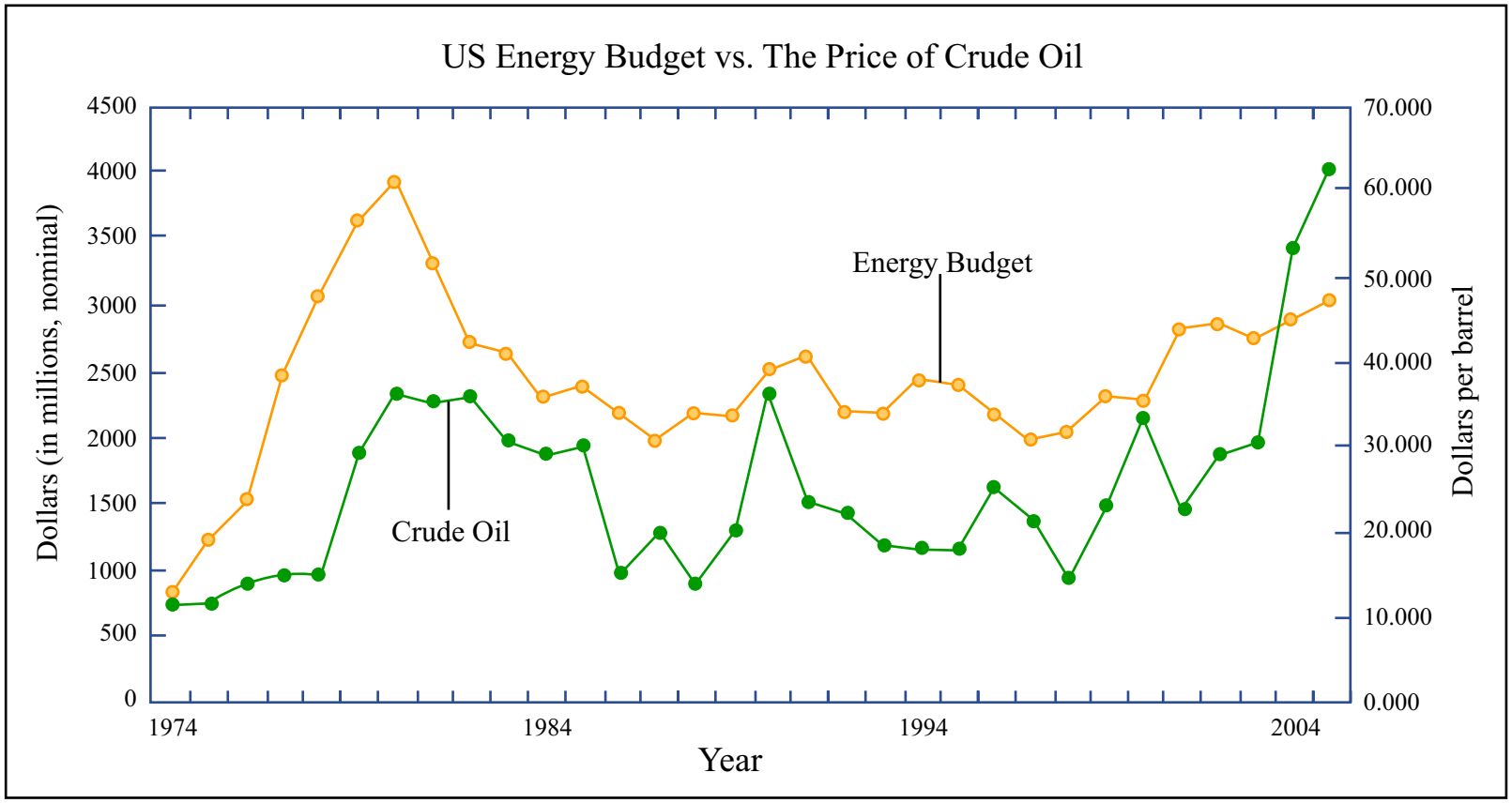
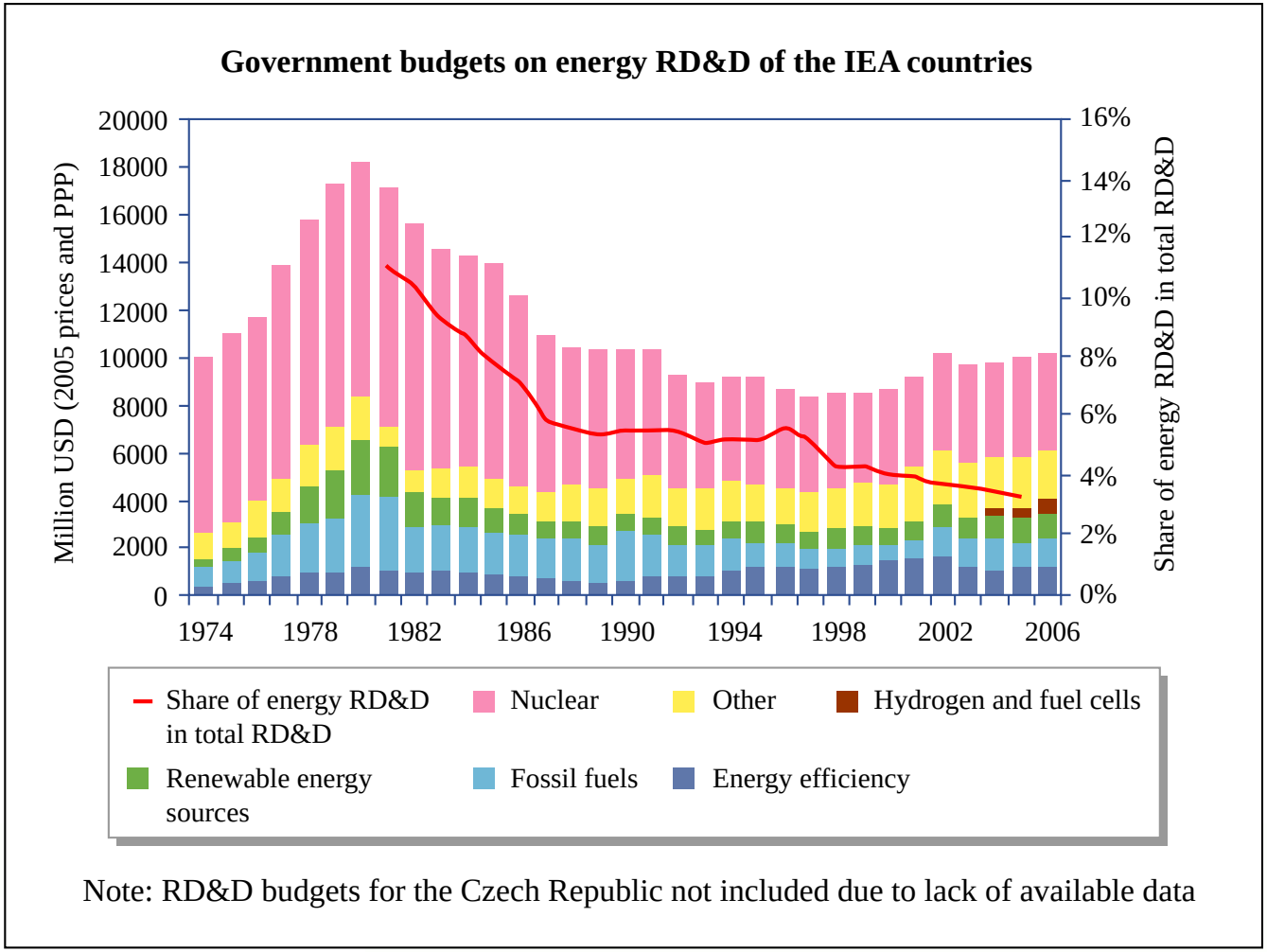



Figure by MIT OpenCourseWare.

-- Neal, Smith, McCormick, *Beyond* Sputnik*: National Science Policy in the 21st Century*, University of Michigan Press, 2008.
Original Sources: Oil prices based upon the yearly average prices per barrel from the Federal Reserve Bank of St. Louis, taken from the Dow Jones and Company data, http://research.stlouisfed.org/fred2/data/oilprice.txt; Energy R&D spending is from the

# IEA: OECD Countries – Similar R&D Decline




Note: RD&D budgets for the Czech Republic not included due to lack of available data

Image by MIT OpenCourseWare.

Source: IEA 2007a, OECD 2007a.

# US Private Energy Sector R&D Investment Compared to that into Sectors with Significant Innovation:

Innovating industries -

- The biotech industry invests 39% of annual revenue,
- pharmaceuticals invest 18%,
- semiconductors invest 16%.

Established industries:

- electronics industry invests 8% of sales
- auto industry invests 3.3%.

# Overall US Industry Average R&D Investment is 2.6% of Sales…

*-->The private energy sector invested on-average less than 1% of annual revenue in new energy tech R&D from 1988-2003*

# Experts: Multiply Energy R&D

| *Recommendation* | *Multiplier* | *US Private R&D* | *US Public R&D* | *Total US R&D* |
|---|---|---|---|---|
| Current Level (FY08) | X1 | $1.2B | $3.6B | $4.8B |
| PCAST (2007), NCEP (2004) ACI (2006), Stern Review (2006) | X2 | $2.4B | $7.2B | $9.6B |
| Council on Competitiveness (2009) | X3 | $3.6B | $10.8B | $15.4B |
| Davis and Owen, Schock, CEPR | X4 | $4.8B | $14.4B | $19.2B |
| Nemet and Kammen, high estimate (2007) | X10 | $12B | $36B | $48.B |

# Is an R&D Increase Justified?

- Precedents for increased government spending on similar scale (in 2002 dollars)
  - Apollo Program ($185 billion over 9 years),
  - Carter/Reagan defense buildup ($445 billion over 8 years),
  - Doubling NIH ($138 billion over 5 years)
  - Ballistic Missile Defense ($145 billion over the first 6 years - actual dollars).

These are examples of the needed size and scope of a technology development program (including implementation), *not* the way such a program should be organized

# IEA: Investments Required for $CO_2$ Reductions are Large:

- The International Energy Agency (IEA) 2008 report estimates
  - Reducing emissions to 50% below 2005 levels -
    - the goal G-8 leaders committed to in July 2008,
  - will require a total worldwide investment of $45 trillion (today's dollars), or $1.1 trillion per year, in R&D and implementation
  - We aren't close

# So….

- Let’s just throw R&D money at it, right?

- But: innovation in established, complex sectors like energy is a much more complicated proposition

# Because the US is a Covered Wagon Culture

- We’re good at completely new things
- Don’t like your neighborhood?
- Take a covered wagon over the mountain to new territory
- This is also true in technology --
  - We’re good at standing up completely new things - creating new functionality.
  - We’re used to standing up technology in open fields - like computing.
  - We pack our metaphorical Tech Covered Wagons and Go West, leaving Legacy problems behind

# U.S. Innovations Like to Land in Unoccupied Territory. Energy is Occupied Territory

- With energy, we'll be parachuting new technology into occupied territory - and will be shot at
- We're not good at going back over the mountain in the other direction - at rediscovering established territory and bringing innovation to it - we don't do West to East
    - We do biotechnology, we don't go back and fix the health care delivery system.
- Yet huge gains not just from the new but fixing the old

# A Complex, Established Sector is a 'Non-Level Playing Field'

- Existing technologies are heavily subsidized and politically powerful
- New entrants are up against an established *Techno-Economic-Political Paradigm*
- Alternative technologies are evolving
- Must be price competitive immediately upon market introduction against legacy competitors that don't pay for environmental or geopolitical costs

# A Carbon Charge

## (Carbon Tax or Cap-and-Trade)

## Market- based Incentive is Necessary

- A price on $CO_2$ captures externalities
- Sends an unmistakable price signal to energy users
- Enables new entrants to enter and start to drive down the cost curve
- Only works if it is sustained and high enough

# But even a Strong Carbon Charge Alone will be Insufficient -- Public Investment is also Needed

- Need both Pricing Strategy and Technology Strategy
  - Why Tech Strategy? Well-known "imperfections in the market" require public investment: doctrine of "non-appropriability,"
- Recent venture capital is for commercialization, not for R&D

What would a new energy technology program actually look like?

How would it be organized?

# A Public Strategy for Energy Technology Should be…

- Very Large in Scale and Scope
  - The problem of energy is scale
  - Comparable to Apollo Project in Size and Scope
  - But NOT in Form or Organization
- Private Sector Led
  - Public-Private Partnerships
- Technology Neutral
  - Avoid technology lock-in

    The opposite of the present pattern of subsidies to specific subsidies with powerful lobbies
    - 'No Lobbyist Left Behind'
- Organized around Obstacles to Market Launch

# New Four-Step Analysis:

- **1. *Launch Pathways:* Group technologies to be implemented into categories based on launch characteristics**
- **2. *Tie to Policy Packages:* Use these launch pathways to guide federal innovation policy roles:**
  - **Bundle policies, available across technologies, so as to be as technology neutral as possible.**
- **3. *Gap Analysis:* to identify gaps between existing institutions in the innovation system**
- **4. *Recommendations for Institutional Innovations* to fill these gaps**

# Step One: Identify Market Launch Categories

1. **Experimental technologies requiring long-term research**
   - **Examples: Fusion, Hydrogen Fuel Cells**
2. **Potentially Disruptive innovations that can be launched in niche markets where they are competitive, and achieve gradual scale-up building from this base.**
   - **Examples: Solar PV's and wind for off-grid power, LED's**
3. **Secondary innovations - uncontested launch: components in larger systems that face immediate market competition based on price, but are acceptable to the system manufacturer.**
   - **Examples: Batteries for Plug-in Hybrids, Enhanced Geothermal**

# Energy Technology Launch Categories – Con't

4. **Secondary innovations - contested launch:**

   **component innovations having inherent cost disadvantages and facing political and non-market economic efforts to block their introduction.**

   – **Examples: Carbon Capture and Sequestration, Biofuels, Nuclear Power**

***Crossover Categories:***

5. **Conservation and end-use efficiency -- incremental improvements for all technologies**

   **Examples: Improved IC engines, BuildingTechnologies, Appliance Standards**

6. **Advances in manufacturing technology and scale-up of manufacturing for all types of energy technology so as to drive down production costs.**

   – **Examples: Wind energy, Carbon Capture and Sequestration**

# Step Two: Policy Packages Matched to Launch Categories

- **(1) *Front End Support*:**
  - **Needed for all technologies**
  - **Examples - research and development (R&D), technology prototyping and demonstrations (P&D), public-private R&D partnerships, monetary prizes to individual inventors and innovative companies, and support for technical education and training**
- **(2) *Back End Incentives* (carrots) to encourage technology deployment:**
  - **Needed for secondary (component) technologies**
  - **Examples - tax credits for new energy technology products, loan guarantees, price guarantees, government procurement programs, new product buy-down programs**

# Step Two , cont'd - Policy Packages for Promoting Energy Innovation

- **(3) *Back End Regulatory and Related Mandates* (sticks):**
  - **For secondary technologies - contested launch**
  - **Prospect of political battles since launch will be contested**
  - **Examples: standards for particular energy technologies in building, construction, and comparable sectors, renewable portfolio standards, fuel economy standards , emissions taxes, general and technology-specific intellectual property policies.**
- Need work on best tools for tech categories

# Step Three: Identify the Gaps in Existing Energy Innovation System

- **"Front-End" - RD&D -**
  - **Translating Research into Innovation**
  - **Carefully monitored demonstrations of engineering-intensive technologies (Carbon Sequestration, Biofuel Processing)**
  - **Improved manufacturing processes**
- **"Back-End" - deployment**
  - **Manufacturing scale-up**
  - **Launching into the economy**
  - **Installation of conservation technology**
  - **Financing infrastructure standup**
- **"Roadmapping"**

# Step Four: Filling the Gaps with the Establishment and Funding of:

- 1) *ARPA-E*: A translational R&D entity - now evolving
  - First $150M awarded to 37 applicants out of 3000+ applications
- 2) *A wholly-owned gov't corporation* for "back end" elements:
  - demonstrations of large engineering projects
  - cut costs of manufacturing technologies and processes
  - Speed the scale-up of manufacturing production capacity
  - Financing installation of conservation, efficiency and related new technologies in residential and commercial markets
  - Both House and Senate energy bills have a "bank"
- 3) *A Think-Tank* to develop a detailed "roadmap" for the requirements for the development and launch of particular energy-related innovations, and to recommend policies to facilitate them

# What else?

- Standards - Critical:
  - to smart grid, to managing ebb and flow of renewables,etc.
  - to offsets - what credits for what kinds of offsets, and for transparency, monitoring systems
  - to assumptions about tech performance and life cycle energy savings
- Test Beds
  - We need to demo performance and optimize new efficiency technologies for different geographies
  - Need to test them as an integrated systems
  - DOD is the largest facilities owner in the US, in wide range of geographies
  - DOD already doing demos of efficiency technologies
  - has energy savings contracting power
  - Could it put up block of facilities with private sector firms bidding for efficiency savings, including tests of new

# A Program Commensurate with the Scope of the Energy Problem Requires Leadership

- This is the toughest Technology Implementation task we have faced -
- nothing else is close

# THE NEXT THING: Energy as a Solution?

- Energy - Next technology revolution?
  - **Could it be new tech *innovation wave*?**
  - **drive efficiency throughout the economy?**

# The Last Innovation Wave…

- 25 years ago
  - Many economists, liberal or conservative, predicted that the GDP$_o$ f the US would fall from first in the world to third.
  - Predicted that by 2007:
    - Japan's GDP would be around $5 trillion,
    - Germany's would be around $4 trillion,
    - US would fall to third at about $3.5 trillion
  - They were partly right. Japan's GDP is about $4.5T, Germany's about $4T.

# More Last Wave…

- But they were wrong about the US. The GDP of the US in 2007 wasn't $3.5T – it was $13T
  - off by $10T
- That's what happens when you bring on a world technology revolution.
  - US brought on two in the 90's: IT and biotech.
- Most economists are now predicting that China will have the world's largest economy by 2040 and the US will fall to second.
- They could be completely wrong.

# More Last Wave…

- Economists: technological and related innovation is responsible for perhaps 2/3's of economic growth.
- The US has led every single significant technological innovation wave since the 1840's,
- The leadership of the next world economy will depend completely on who leads the next big world innovation wave.
- There appears to be a substantial argument that that wave will be built around new energy technology.
  - Energy is 12% of the world economy.
  - Transforming energy transforms the economic foundation of our economy because energy changes the economics and efficiency of nearly everything.

# Tech Revolutions cost money - Where will the $ come from?

- Big FY10 stimulus program for Energy: $39B ($5B R&D)
- Cap and Trade only significant new revenue source
- Funding will fall off a funding cliff after Stimulus
- The Administration understood this and proposed:
  - FY2010 $150B "Clean Energy Tech Fund" from cap and trade revenues
- ***BUT: not funded in House or Senate cap and trade bills***
- And budget cutbacks for R&D in FY11

# What are others upto?

- China
  - $400B/10 year clean energy tech program- ACORE
  - $3/watt subsidy for solar - largest in world
  - Wind: 150GigaWatts (GW) by 2020
  - World's largest solar panel mfg. industry – 95% exported to US
  - World's largest wind market (passed US)
  - Mercantilism: barring imports of wind/solar technology into China via standards, etc policy
- Korea
  - 2% of GDP in clean tech: $84B over 5/years
  - Wants 8% global market share
  - LED's, plug in hybrids
- India
  - 2020 target for solar: 20GW's (sources: NYT, Wash Post)

# US Response?

- There is no true US Energy Technology Strategy yet
- The Administration's energy technology funding is not faring well on the Hill
- Budget crunch hitting

# The Four Strategies…

- Need an energy innovation strategy
  - That brings in the private sector
  - Treats innovation as a system
  - Ties in energy science/engineering education
  - Need standards and testbeds
- Need get to a tech roadmap for energy
  - If energy is to be an innovation wave a roadmapping process between public-private-academic sectors needed
- Need an energy tech manufacturing strategy
  - required to reverse the covered wagon
  - Need productivity leapfrog - AI, robotics, processes, materials
- And Key: Need a long term energy innovation funding strategy
  - headed off a cliff after Stimulus FY10 funding

# Resource: Science Policy Bootcamp

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