Moving Energy Innovation to Scale

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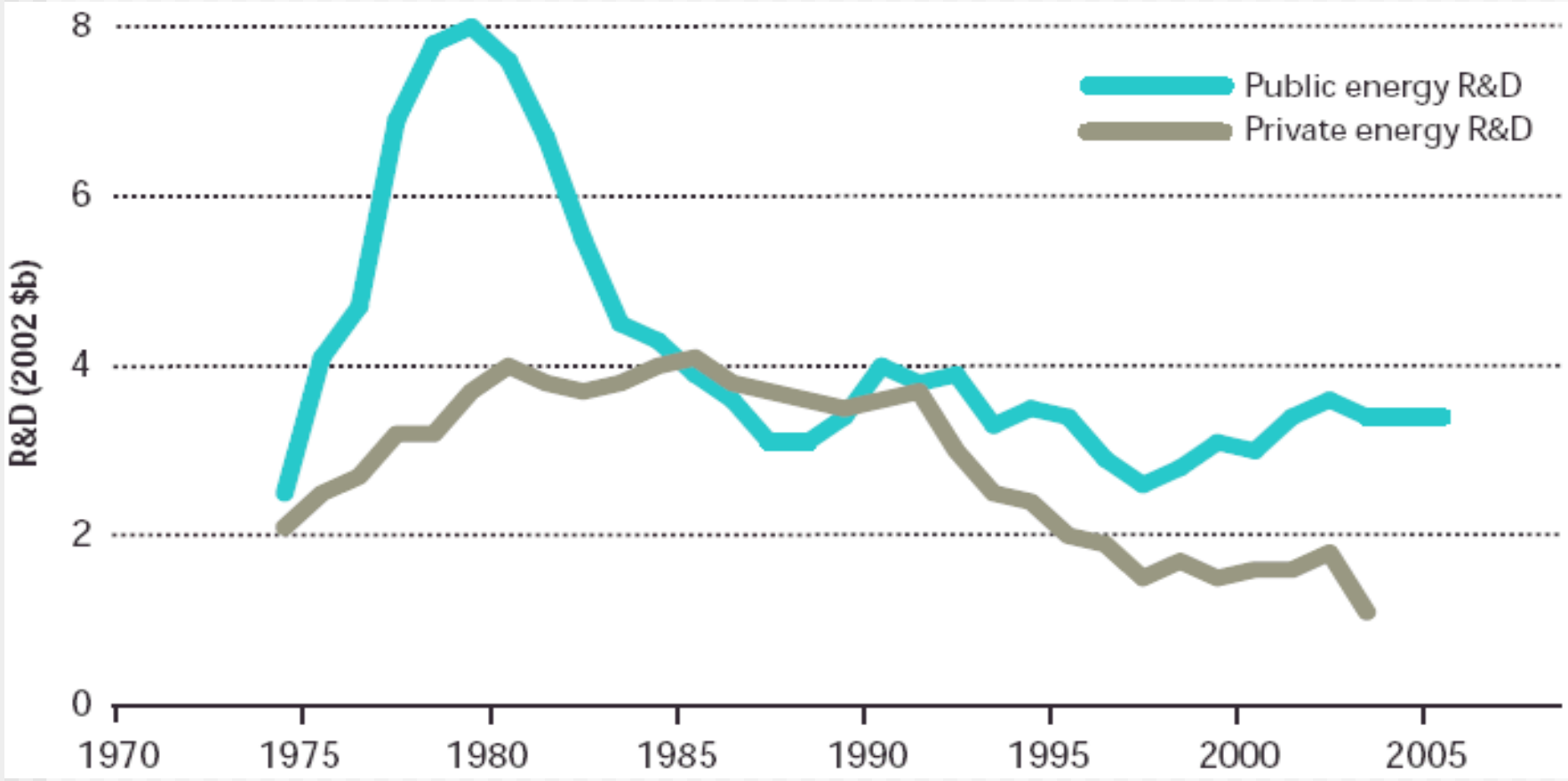
US Public and Private Trends in Energy R&D:



(Source: Nemet and Kammen, 2007)

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%.

- Average R&D to ann. rev., all US industry: 2.6%
- Private Energy Sector: less than 1%

(Data from: Nemet and Kammen, 2007)

Is an R&D Increase Justified?

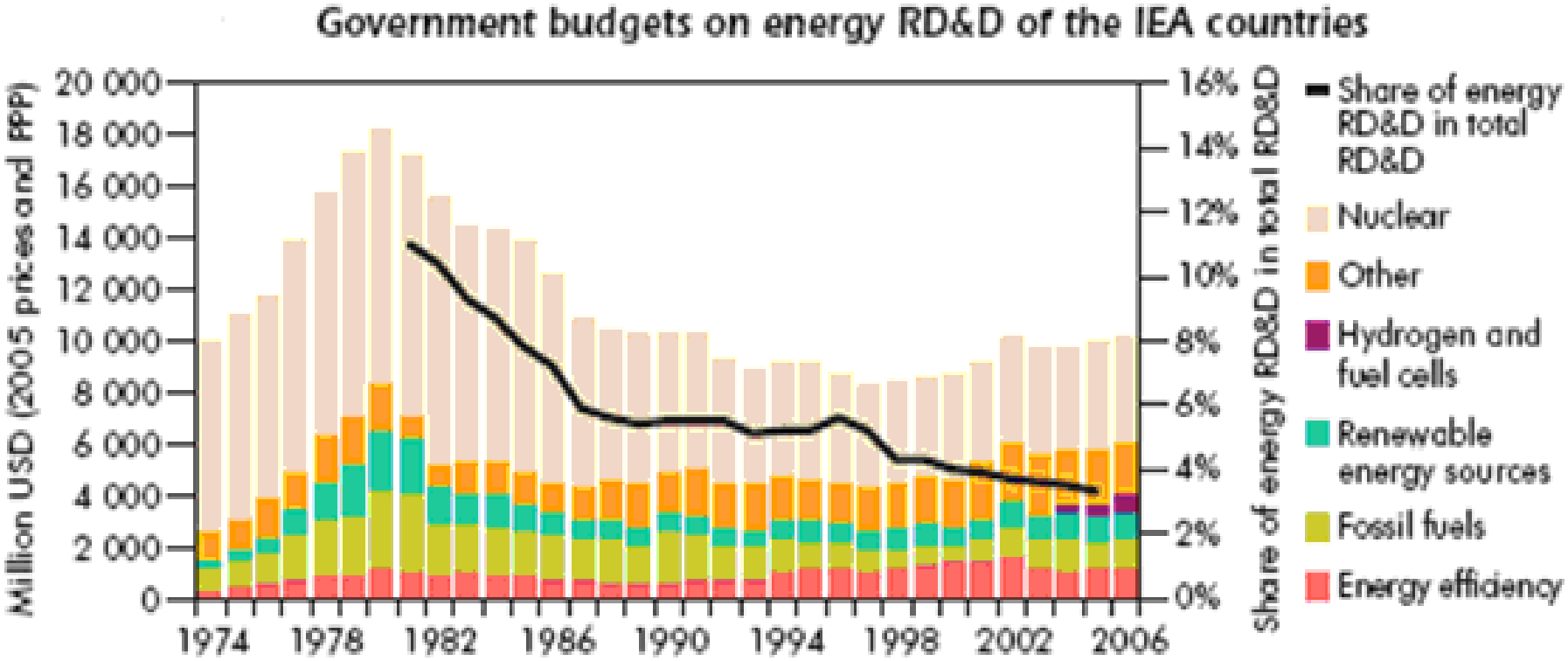
- Precedents for increased government spending on similar scale (in 2002 dollars)
  - Apollo Program ($185 billion over 9 years),
  - Carter/Reagan defense buildup ($445 billion over 8 years),
  - Doubling NIH ($138 billion over 5 years)
  - Ballistic Missile Defense ($145 billion over the first 6 years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

International Energy Agency: Perspectives 2008: Scenarios and Strategies to 2050

- The International Energy Agency (IEA) 2008 report estimates:
  - IEA: Investments Required for CO2 Reductions are LARGE
  - 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% of GDP, 1,1T/year
    - in R&D *and* implementation
  - CO2 Stabilization also very expensive - $17T by 2050.
  - We aren't close

IEA: OECD Countries – Similar R&D Decline



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

Source: IEA 2007a, OECD 2007a.

IEA 2008, con't

- Tech revolution in energy is possible and "urgent"
- Deep emission cuts are "technically achievable"
- Barriers:
  - Financing needs
  - Slow capital stock turnover
  - Timeliness of bringing on new technology

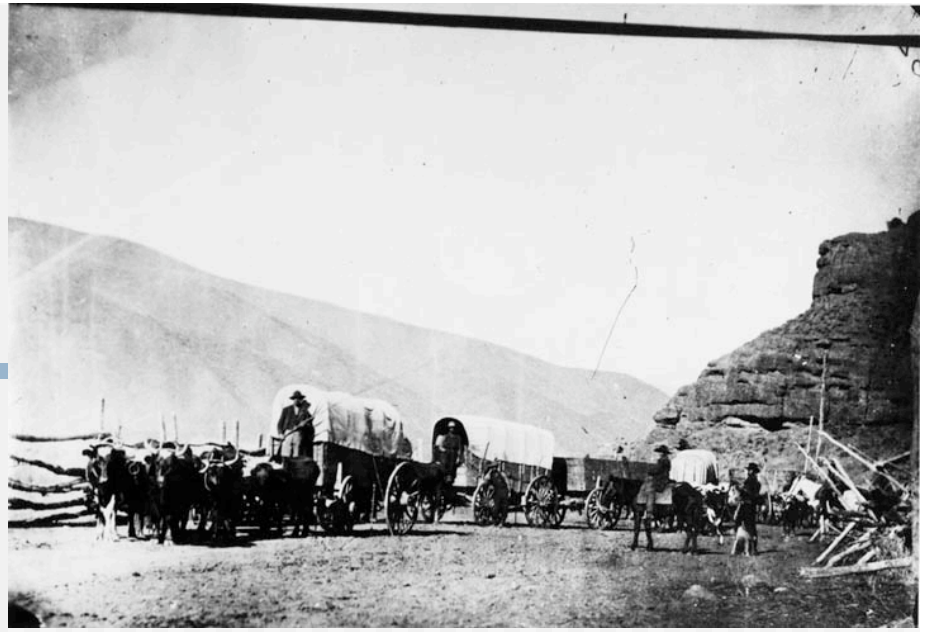
The point:

- Getting to energy R&D and technology implementation at scale is a big problem

BUT…

- Just throwing money at Energy R&D is not enough
- Innovation in an established, complex sector like energy is a much more complicated proposition

The US is a Technology Covered Wagon Culture



- 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
- We rarely take our tech covered wagons west to east

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

- Energy technology will be <u>parachuting new technology into occupied territory</u> -
- - and will be <u>shot at</u>
- <u>Yet huge gains</u> not just from the new but fixing the old

Energy is a Complex, Established Sector

- Existing technologies are heavily subsidized and politically powerful
- New entrants are up against an established *Techno-Economic-Political Paradigm*
- Alternative technologies 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

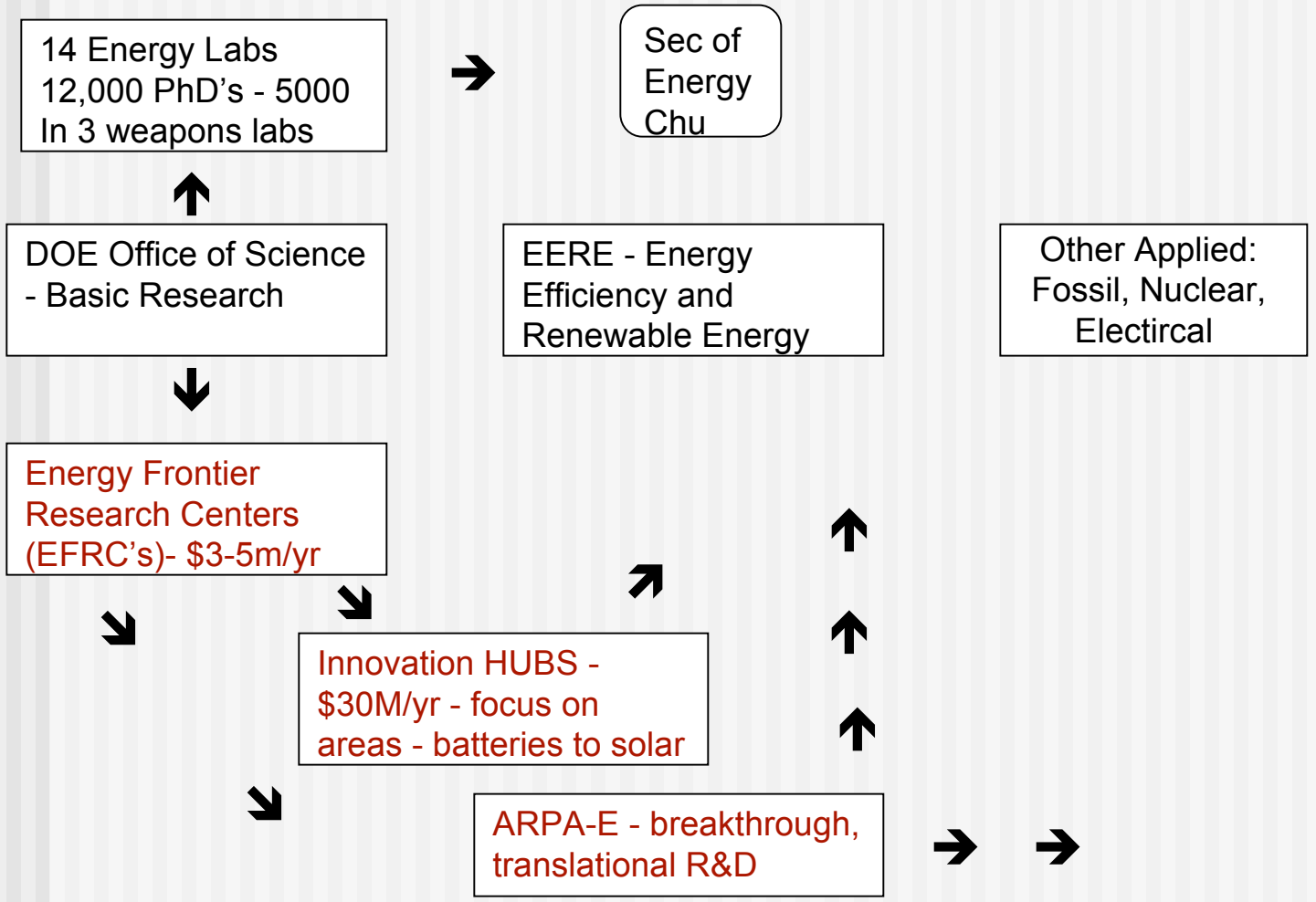
- A price on CO_2 captures externalities
- Sends an unmistakable price signal to energy users
- Enables new entrants to enter and start to drive down the cost curve
- Only works if it is sustained and high enough
- So a pricing mechanism is NECESSARY BUT NOT SUFFICIENT
- Must have parallel R&D/implementation initiative

The Institutional Problems with Energy Innovation System -The Front End Problem:

- DOE Sec Chu standing up ARPA-E
  - DARPA translation research
  - Breakthrough oriented accelerator
  - Will it get next $300m in FY11 from Congress? Then Scale?
  - What is its constituency - is the political model right?
- The Other Pieces Chu seeks:
  - Energy Frontier Research Centers (EFRC's) - now 46 - $3-5m
    - Effort to engage university base in basic energy research;
  - Energy Innovation HUBS - mini-Bell labs - scale/incremental work in key areas: solar, batteries, advanced nuclear, building efficiency; $20+m/year
  - Re-energyze - energy education; no revolution without trained troops - but in trouble on the Hill: sci ed is an NSF role

Front End of DOE's Evolving Innovation System:

Research ---> to Applied ---> to Demonstration ---> to Commercialization



The Problem with the Innovation Back End:

- DOE is all Front End - not focused on the Back End of the Innovation System
  - In a complex established sector there won't be efficient innovation on the back end - need a public sector role in the back end
- -Other key institutions: DOE needs -
  - Need **Financing Bank**
    - House & Senate Energy proposed this year in energy bills
    - Chu: standing up loan guarantee based on 05 and 07 energy acts - but need a variety of tools - loan guarantees not relevant to all start-ups and small firms
  - Need gov't corp. for large scale **demonstrations**
  - Need **Testbeds**
    - DOD largest facilities owner in US - $20B/year in military construction
  - Need **Tech Strategy** leading to **Energy Roadmap**
    - We have a tech list not a strategy and long way from Roadmap

The DOD Systems Model

- DOD did the IT revolution by playing at every stage of the innovation system
  - From research to development to demonstration to testbeds to financing to procurement to create the initial market
- An energy transformation is at least as hard as IT
- We're going to need to play at all the stages of the system

Another Problem: Technology Neutrality in Energy Legislation

- Bills written backward
  - Each technology has it's own title, own funding stream, many separate disconnected innovation strands -- each has own deal
  - More powerful your lobby, more powerful your title - farmers = biofuels - No lobbyist left behind
  - Need to avoid technology lock-in - 40 year problem
  - Reverse: set up tech neutral incentives
    - See Steps 1 and 2 above - need overall system
  - Need better level of technology neutrality - hard in a political world of established sector
  - Let best technologies compete for support based on energy merits

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

- Energy R&D Approp's stagnant in 2008-09, but Stimulus provided major new R&D funding input for FY10
  - $5.5 R&D and infrastructure; $34b late stage implementation
  - But: US deficit/fiscal posture an ongoing problem
- Cap and Trade only significant new revenue source
  - Funding will fall off a funding cliff next year and lose momentum unless a follow-on funding source is found
- The Administration understood this and proposed:
  - FY2010 President's Budget proposes $150B "Clean Energy Tech Fund" from cap and trade revenues - but Administration has sought no funding for it
- ***June 2009: House Energy Committee cap and trade bill passed - only $1.5B in R&D funding***, $8B go to coal, utility, oil refinery, auto sectors, states: tech deployment only
  - ***Senate bill*** being negotiated: not clear if add'l R&D funding

Energy as an Economic Wave -

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

But: Problem of "New Functionality"

- IT: new functionality added to the US economy - major new functions, accompanying productivity gains
- Energy - more complicated
  - Still have cars, electricity still from wall outlets
  - But: over time: new functionality - LED light walls, distributed power - takes time to evolve
  - Throughout: efficiency gains that translate over time into productivity gains in all sectors
  - Productivity gains crucial to innovation waves

Pres. Obama:

- "We can cede the race for the 21st Century, or we can embrace the reality that our competitors already have: The nation that leads the world in creating a new clean energy economy will be the nation that leads the 21st century global economy." 6/29/09

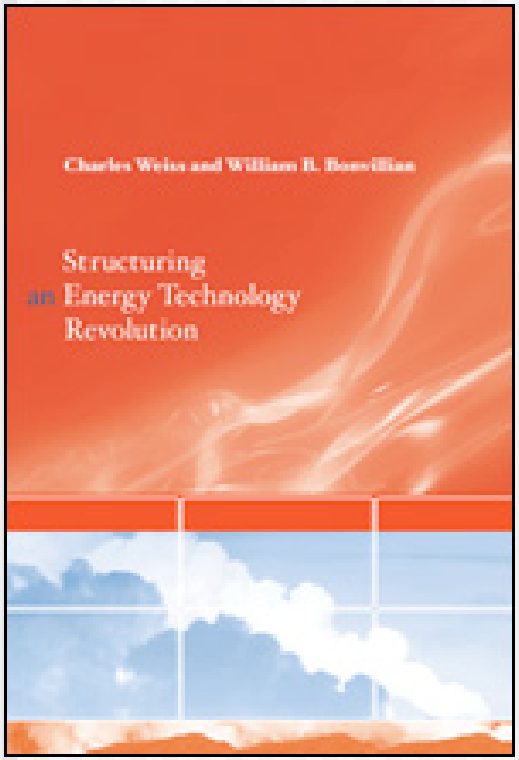
What are others up to?

- Pew Center *Who is Winning the Clean Energy Race? Growth, Competition and Opportunity in the World's Largest Economies (2010).* **www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/.../G-20%20Report.pdf**
- Information Technology Innovation Foundation/ Breakthrough Inst., *Rising Tigers, Sleeping Giant: Asian Nations Set to Dominate the Clean Energy Race by Out-Investing the United States (2009).* **http://archive.itif.org/index.php?id=315**

Admin. Needs the 4 Strategies:

- Need an energy innovation system strategy
  - That brings in the private sector
  - Treats innovation as a system
  - Ties in energy science/engineering education
  - Adequately funds the Front End
  - Puts in a Back End - includes financing, testbeds
- Need a 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 ends

APPENDIX:



INNOVATION SYSTEM STEPS -

From: Weiss & Bonvillian, *Structuring an Energy Technology Revolution* (MIT Press 2009)

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, con't - 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
- 2) A *wholly-owned gov't corporation* for "back end" elements:
  - Sharing the financing of carefully monitored demonstrations of large engineering projects
  - Encouraging and incentivizing industry consortia to 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
- 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