

# Class Five: The Challenge of Energy Technology

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*MIT IAP Seminar: “Fundamentals of  
Science and Technology Public Policy-  
Making”*

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# RECAP ---

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CLASSES

ONE, TWO, THREE,  
FOUR

# Summary from Class One – Innovation Economics:

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- **Solow** – key to growth: “technology and related innovation” (shorthand: R&D)
- **Romer** – behind technology: “human capital engaged in research” – prospector theory (shorthand: Talent)
- **Jorgenson** – key to 90’s growth: SC’s, multiply productivity throughout economy
- **Direct Innovation Factors** -
  - R&D and
  - Talent

# Class One Summary, con't

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## ■ NELSON:

- Idea of innovation as a complex system
- Operates at a national scale
- Can do comparative analysis of national innovation systems
- System operates at the INSTITUTIONAL LEVEL -look a connections, interaction between innovation actors in public and private sectors

## ■ INDIRECT INNOVATION FACTORS, TOO

- Mix of indirect and direct innovation factors in interacting in an innovation ecosystem

## ■ BRANSCOMB AND AUERSWALD

- Valley of Death between R&D
- Not linear, a Darwinian Sea

# Class Two – The Organizing Framework Behind US Science Agencies

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- David Hart – the ideologies behind US S&T
  - Associationalism,
  - Conservatism,
  - National Security State,
  - Keynesian

# Class Two, Summary, con't

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- Donald Stokes - *Pasteur's Quadrant* -
  - WW2 - Vannevar Bush creates a connected model for innovation
  - Post-war - creates research univ., basic research only, disconnected model - institutionalizes the “Valley of Death”
- Bush belief: understanding and use are conflicting goals, so basic and applied research must be separated
- “applied research drives out pure”- V. Bush
- No wonder US has had historic trouble converting its leadership in technology inventions into products – Bush made this a suspect activity -and assumed advances flowed left-right, research to applied
- Bush's segmented linear/pipeline model:

**Basic--> applied--> development--> production  
& operations** <sup>6</sup>

# Stokes' PASTEUR'S QUADRANT:

## Consideration of Use?

No

Yes

Yes

Pure basic  
research –  
Ex- Nils Bohr

Use inspired  
basic research  
– Ex- Louis  
Pasteur

Search for  
fundamental  
under-  
standing

No

Review of the  
particulars not  
the general  
-- early Darwin

Pure applied  
research –  
Ex-Thomas  
Edison

# Class Two, Summary, con't

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- So: most of US R&D on basic research/pipeline model -- but there is a parallel universe:
- Vernon Ruttan - *“Is War Necessary for Economic Growth”*
  - DOD rebuilt the connected model of WW2 for the Cold War
  - Launched: nuclear, aviation space, computing, internet
  - DOD: Pervasive role at all stages of the pipeline - from R to D to prototype to demonstration to creating initial market

# Class Two Summary, Con't

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- Bonvillian: DARPA model – innovation at the institutional level – connected science, and initiator of great groups
  - Right-left; revolutionary breakthroughs
  - Challenge model

# Class Three, Summary

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- Innovation organization as the third innovation factor:
  - Institutional and face-to-face
- Bennis/Biederman – great group theory
  - The Great Groups Ruleset
  - Industrial Revolution, Edison, Rad Lab, Oppenheimer, Transistor group, Xerox Parc – Bob Taylor, Genentech, Venter, DEC

# Class Four, Summary:

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## ■ Kent Hughes

- Competitiveness challenge of the 70's-80's
- Japan captures an innovation wave around manufacturing
  - Quality/Price trade off; just in time inventory; labor as a fixed cost; integration of supplier base, etc.

## ■ Paul Samuelson

- Comparative advantage in innovation is not permanent – it can be captured
  - But closing borders risks economic arteriosclerosis

# Class Four, Summary, con't

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- Suzanne Berger
  - Distributed mfg enabled by IT specs
  - Model airplanes vs. legos – iPod example
  - Separate design from production
- Glenn Fong
  - Pursuer of the Pioneer, to follower at the frontier, to world class technology origination
  - Japan's MITI moves to a decentralized model

# Class Four, Summary, con't

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- Linsu Kim
  - Korea as example of emerging economy
  - Innovation-based growth model works\
  - Role of culture in innovation
- Greg Tasse//Pisano & Shih
  - Challenges to US mfg. leadership
- William Raduchel
  - Software as the key to value and organizing principle of the modern corporation
  - Issue – the software is the firm
  - India: software leadership

# Now – Class Five – The Energy Technology Challenge

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- Case study for what we have learned so far – but: new - complex established sector problem
- The issue of innovating in complex established sectors
- The US avoids it
- Energy could be a model

**Stephen W. Pacala and Robert H. Socolow,**  
*“Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies”, Science (Aug. 13, 2004)(also: Sci. Amer. 2005)*

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- Fifteen major energy initiatives
- Seven of which, if they grow into large wedges of energy supply, could bring emissions down during the next fifty years to a 2005 stabilized level
  - (estimate as avoiding about a third of the total CO<sub>2</sub> emissions that would otherwise be released.

# Socolow & Pacala, Con't

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- Some of these wedges are clearly within the range of adoption and timely scale-up.
- Others—reduced deforestation, a 50 percent reduction in driving by two billion vehicles, or widespread adoption of conservation tillage, for example—would, as the two authors recognize, require major changes in policy and behavior that could take extended periods.
- Still others, like technology for carbon capture and sequestration, are likely to take years of development and demonstration before they are ready for widespread deployment

# Socolow & Pacala, Con't

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- “We agree that fundamental research is vital to develop the revolutionary mitigation strategies needed in the second half of this century and beyond. But it is important not to become beguiled by the possibility of revolutionary technology. Humanity can solve the carbon and climate problem in the first half of this century simply by scaling up what we already know how to do” – the authors

# Bonvillian and Weiss, *Taking Covered Wagons East*, (Innovations, 2009; & see MIT Press book *Structuring an Energy Tech. Rev.*)

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- Need to get inside the “black box” of energy innovation
- Gov’t already deeply interventionist -
  - regulatory, subsidies to fossil and renewables
  - Political parties:
    - R: nuclear, domestic oil production, natural gas - subsidies
    - D: renewable subsidies
    - Both: missing coherent energy tech policy
    - Overlap: agreement on new energy technologies
- Few new energy technologies technological and economically ready for implementation
  - Policy concensus on need for new technologies, but few detailed attempts on how to implement them

# Scale and Price Issues in Energy

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- New energy technologies must land in a complex, established sector
  - A “techno-economic-political paradigm”
- Private sector R&D discourage by wild price oscillations in energy prices
  - Oil \$20/barrel 1998, \$140/barrel 2008
- Public sector - 40 years of promises of “energy independence” yet few technologies have transitioned
  - An historic political system failure
- Need for parallel and supporting policies on price and on technology supply

# A Public Strategy for Energy Technology Should be...

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- 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

# The 3 Innovation Theories: Pipeline, Induced, and Organization

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- Energy requires new unified theory of innovation
- Model One: Pipeline --
  - Vannevar Bush and WW2 - connected science
  - Technology push model
  - Federal research based
    - More research than development
  - radical/breakthrough research advance
  - Remember Branscomb/Auerswald - It's not really a pipeline
  - In energy, we will need to strengthen our pipeline model capability

# The 3 Innovation Theories, Con't

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## ■ Model Two: Induced Innovation

- Industry-led - industry identifies a market opportunity to be met with innovation
- Typically incremental advance
- “Demand-Pull” or “Technology-Pull”
- More Development than Research
- Developed by economist Vernon Ruttan
- In energy, a carbon price can supply the demand push factor

# The 3 Innovation Theories, con't

- Model Three: Innovation Organization
  - Management of innovation and the institutions and institutional arrangements required in this category
  - Technology push and Demand Pull are not enough in energy - will need new innovation organization
  - **Will need in energy an integrated theory featuring all three models**
    - Unlike IT, which was essentially tech push from DOD
  - **Energy will require filling innovation institutional gaps**

# Summary –

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- **Bonvillian and Weiss, “Covered Wagons”:**
  - The problems of scale,
    - and techno-eco-pol paradigm
    - and established complex sector
    - Technology neutrality
  - Integrating the 3 Models of Innovation -
    - Pipeline - “technology push”
    - Induced - “demand pull”
    - Innovation organization
  - Energy demands all 3 models be integrated, unified

# Scaling Energy Innovations

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## ■ Investment Levels 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: (Nemet and Kammen)

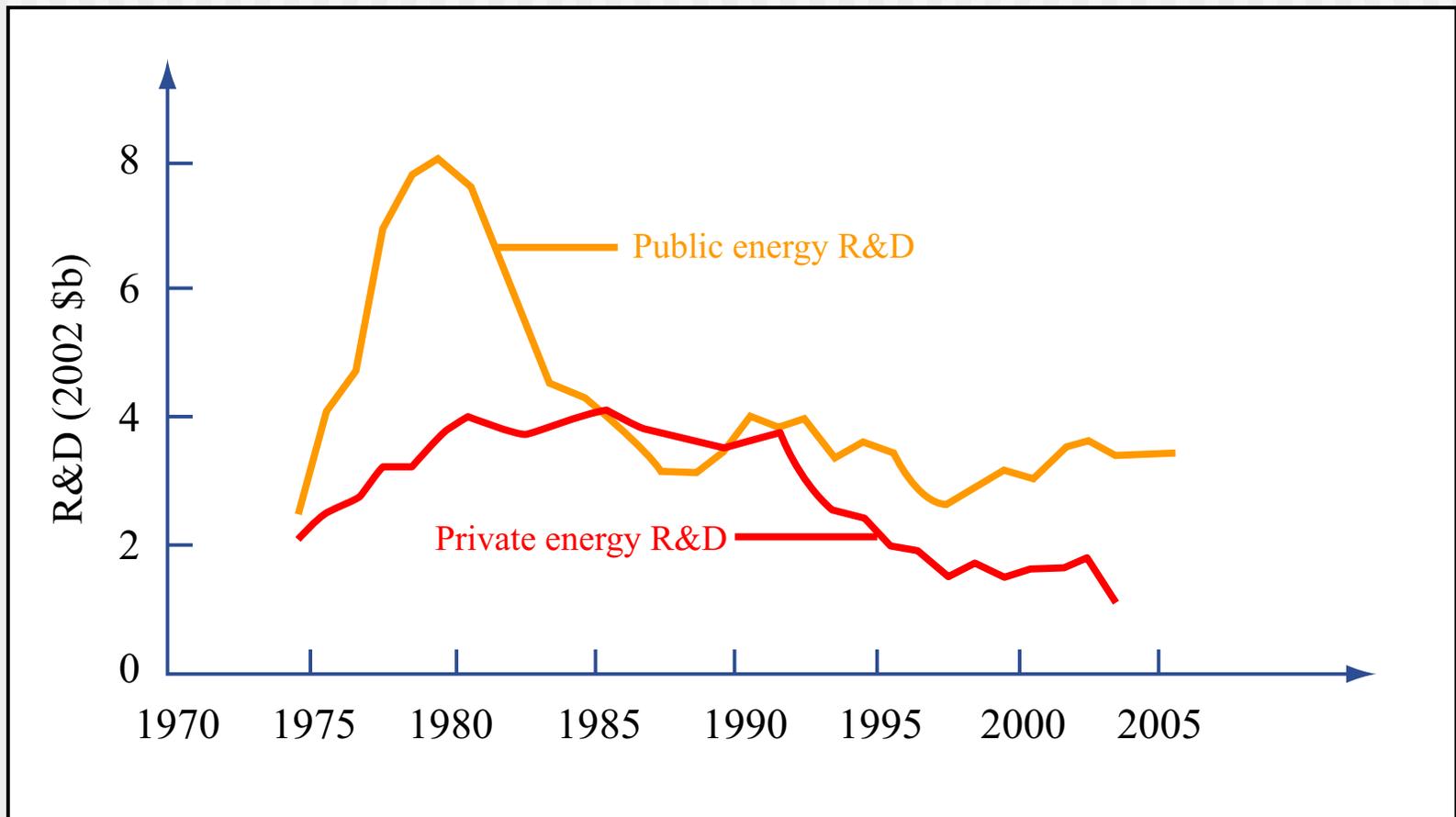


Image by MIT OpenCourseWare.

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

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## 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/ann.rev., all US industry: 2.6%
- Private Energy Sector: less than 1%

# 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

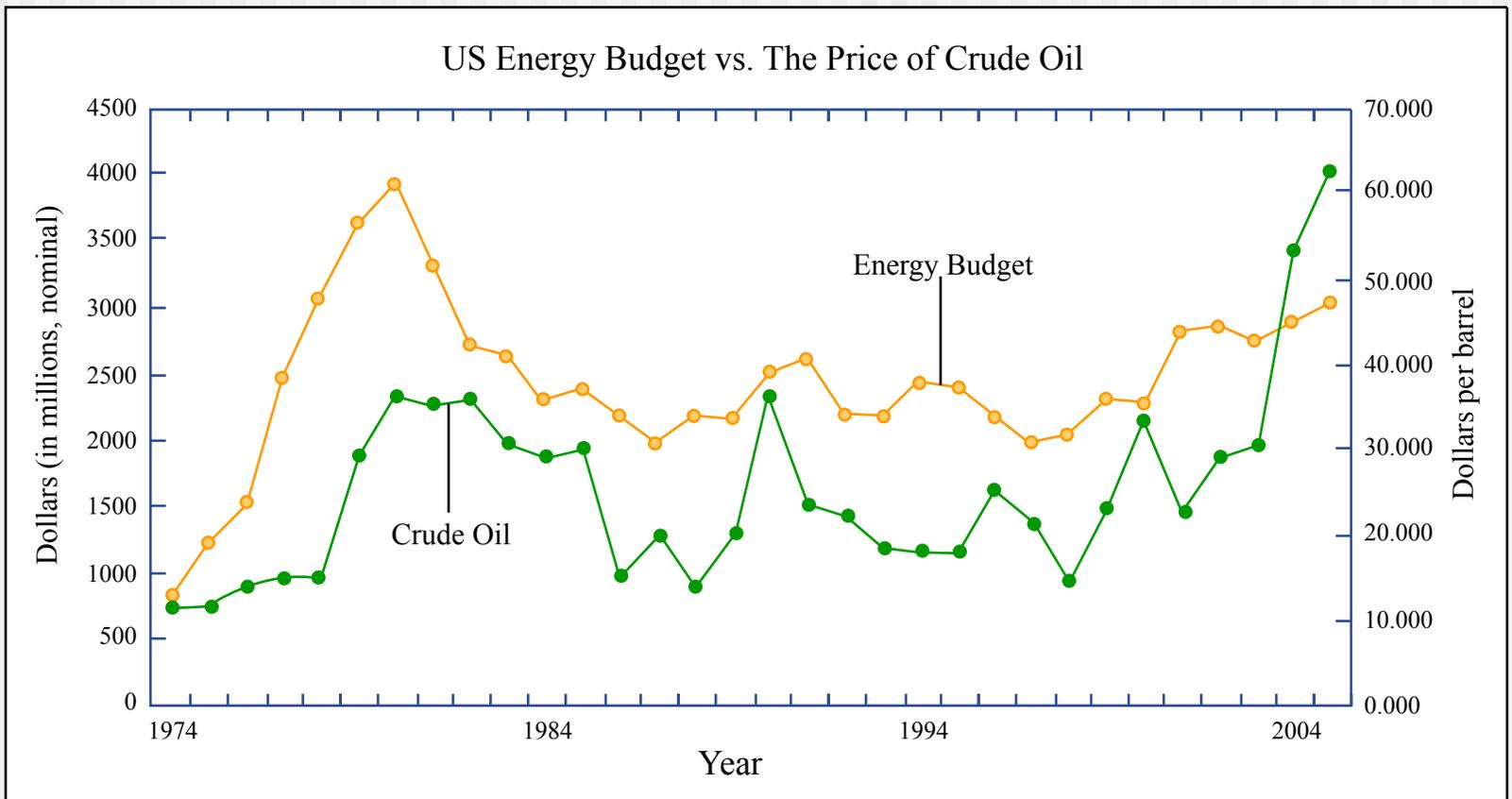
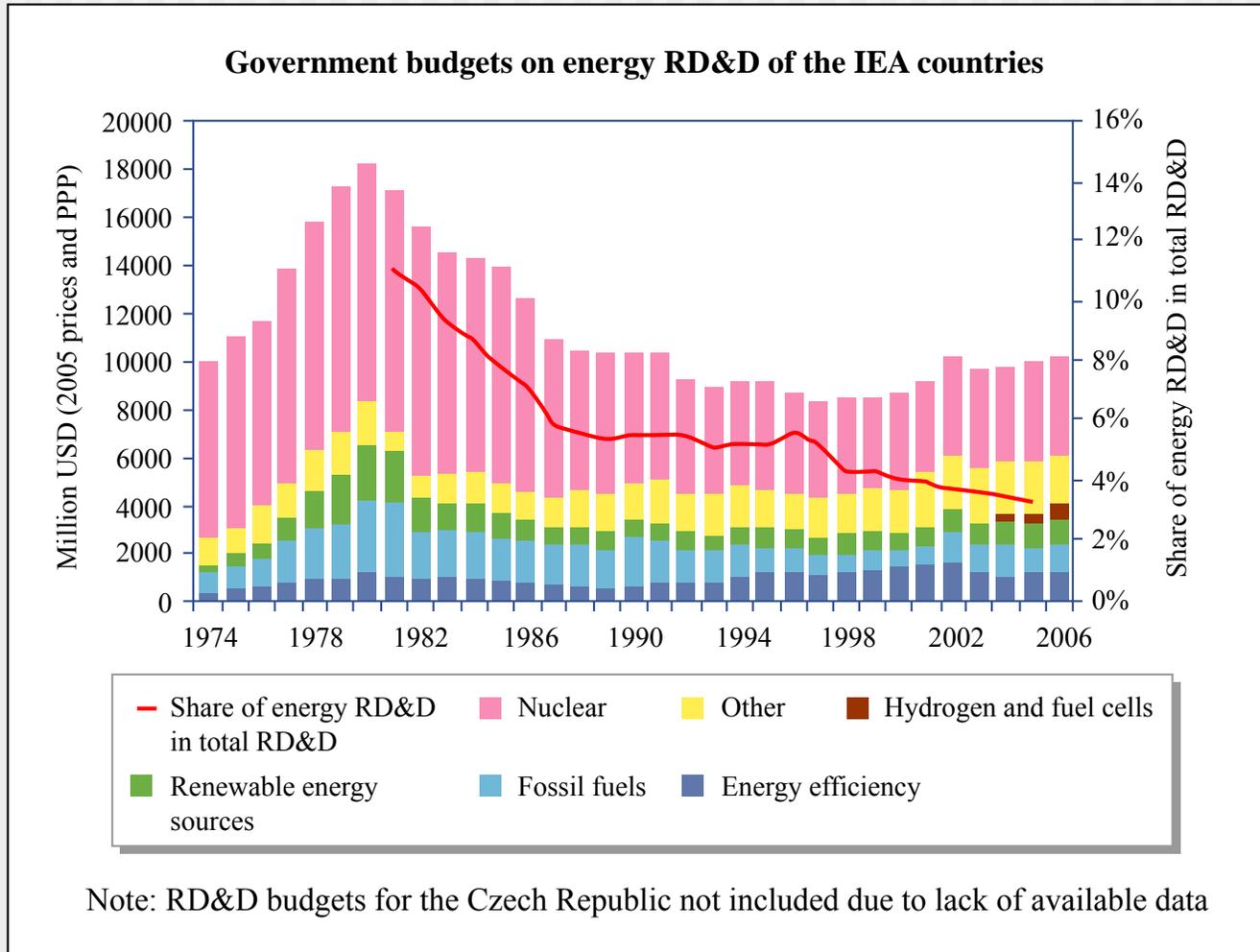


Image by MIT OpenCourseWare.

# IEA: OECD Countries Similar R&D Decline



# IEA: Investments Required for CO<sub>2</sub> Reductions are Large:

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- 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...

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- 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

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- 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

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- 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'

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- 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 would be Important

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- A price on CO<sub>2</sub> 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

# To Reiterate:

## 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:

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- 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

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

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

# 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, Building Technologies, 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

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- (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

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- **(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**

# Bonvillian and Weiss, Con't

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- STEP 3: Identify the Innovation System GAPS
- Step 4: Fill these GAPS - content of Chapter 6
- Need to identify the gaps on the:
  - FRONT END and
  - BACK ENDin the Innovation “pipeline” -
  - at every stage from: Research to Development to Prototype to Demonstration/Testbed to Deployment and commercial market

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

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- **“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

# What Else?

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- **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 - proof of practice, cost control
  - Need to test them as an integrated systems
  - DOD is the largest facilities owner in the US, in wide range of geographies; also: huge energy dependent operations
  - DOD already doing demos of efficiency technologies
  - has energy savings contracting power and \$20B/yr MilCon approp's
  - Could it put up block of facilities with private sector firms bidding for efficiency?

# Problem of “New Functionality”

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- 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
- Consumers will pay a premium for first generation of new functionality products
- But first gen of new energy won't offer much new functionality
- So: still need a price on carbon to introduce new technologies at scale

# Summary – Bonvillian & Weiss

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- Need 4 step process
  - Figure out launch categories, group them
  - Apply right incentive packages to each launch category
  - Evaluate gaps in the innovation system
  - Fill the gaps
- Must have both frontend and backend initiatives in a complex, established sector

# *John M. Deutch, What Should the Government Do to Encourage Technical Change in the Energy Sector? (May 2005)*

- Gov't controlled corporation model:
  - Moves demo politics out of Congressional reach
    - Pork barrel reaches anything over \$50m
  - Get outside procurement system limits
  - And need upfront funding base - must get outside Appropriations process of Cong'l intervention
  - Can hire commercial quality engineering and financing talent, and compensate them, unlike gov't
  - Well-understood model: Fannie Mae; Ag crop ins., many examples - need oversight and clear limits, but can operate as combo bank and investment bank as well as operating entity, like Amtrak and Comsat

# John Deutch, Con't

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- Carter Admin. went wrong with major demonstrations
  - synfuels, coal gasification, etc., then oil prices collapsed - killed effort
  - Funded by annual Appropriations - politics set demonstration sites
    - Hence need for independent gov't corp. with initial financing base
- Key lesson in current efforts - must deal with price roller coaster for oil - otherwise even independent gov't corp. won't work

# John Deutch, Con't

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- Other tasks for corp?
  - Financing manufacturing scale-up?
  - Financing mfg process and technology improvements?
  - Financing residential and small commercial building energy conservation (buildings 40% of the problem)?

# Alic, Sarewitz, Weiss, Bonvillian, *Nature* – Role of DOD in Energy

- DOE only innovates up to the prototype stage
- But testbeds and initial markets are needed in energy
  - We needed them in IT, why not energy?
- It does not buy or sell technologies
- DOD does – and has a vital interest in energy – strategic and tactical
- DOD could supplement the role of DOE on the innovation backend – fill a gap

# Dorothy Robyn, Deputy Undersecretary of Defense for Facilities and Environment – DOD Energy Role

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- DOD – largest facilities owner in US, by far
  - 507 installations and bases
  - 300,000 buildings
  - 2.2 billion square feet of space
  - 160,000 cars and trucks
  - In every US geographical area and region
- Consumes 1.7% of US oil
  - Spent \$13.4B on energy in 2009; \$20B in '08
  - 300,000 barrels a day

# DOD Testimony, Con't

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- Perhaps half US defense budget spent on defending oil lines of communications (\$300+B “externality”)
- **DOD has a strategic problem** – it’s profoundly oil dependant and oil supply is vulnerable if a major supplier country fails
  - And it’s fighting two wars in part because of oil supply
- **DOD has a tactical problem** –
  - Energy supply lines are prime casualty cause
  - Forces Army into poor tactical position – defending fixed supply points and vulnerable supply lines – block Army from flexibility and response capability
- **DOD has Facilities Cost Problem** – must cut costs, and reducing O&M costs at bases is key

# DOD Testimony, Con't

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- Every year, DOD receives \$20B in Military Construction appropriations – for rehab and new buildings of all types
- This funding stream is potentially transformative – could leverage major transformative investments in new technologies
- DOD also has profound experience operating testbeds
- Testbeds a crucial need in building technologies –
  - Decentralized small scale, mom&pop industry, slow to innovate, funds no R&D
  - Will not innovate unless proven reliability, proven efficiency, proven cost performance
- DOD also needs: distributed power, powerful low cost batteries, biofuels for aircraft/ships, efficient transport, etc.

# Deutch, Alic and Robyn – “Backend” ideas

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- Deutch – the wholly owned gov’t corp.
- Alic et al – impt. DOD role in energy in playing its systems role in innovation
- Robyn – DOD as testbed and initial market
- All: Backend ideas
- *Where are we on the Front and Backend?*

# Bonvillian, “Time for Plan B for Climate” (Issues for S&T- Winter 2010-11)

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- Cap and Trade – structural problem – it’s neoclassical economics, therefore it’s not focused on innovation policy
- As noted above, both demand side (cap and trade) and tech supply side (energy innovation) will be needed

# The Institutional Problems with Energy Innovation System

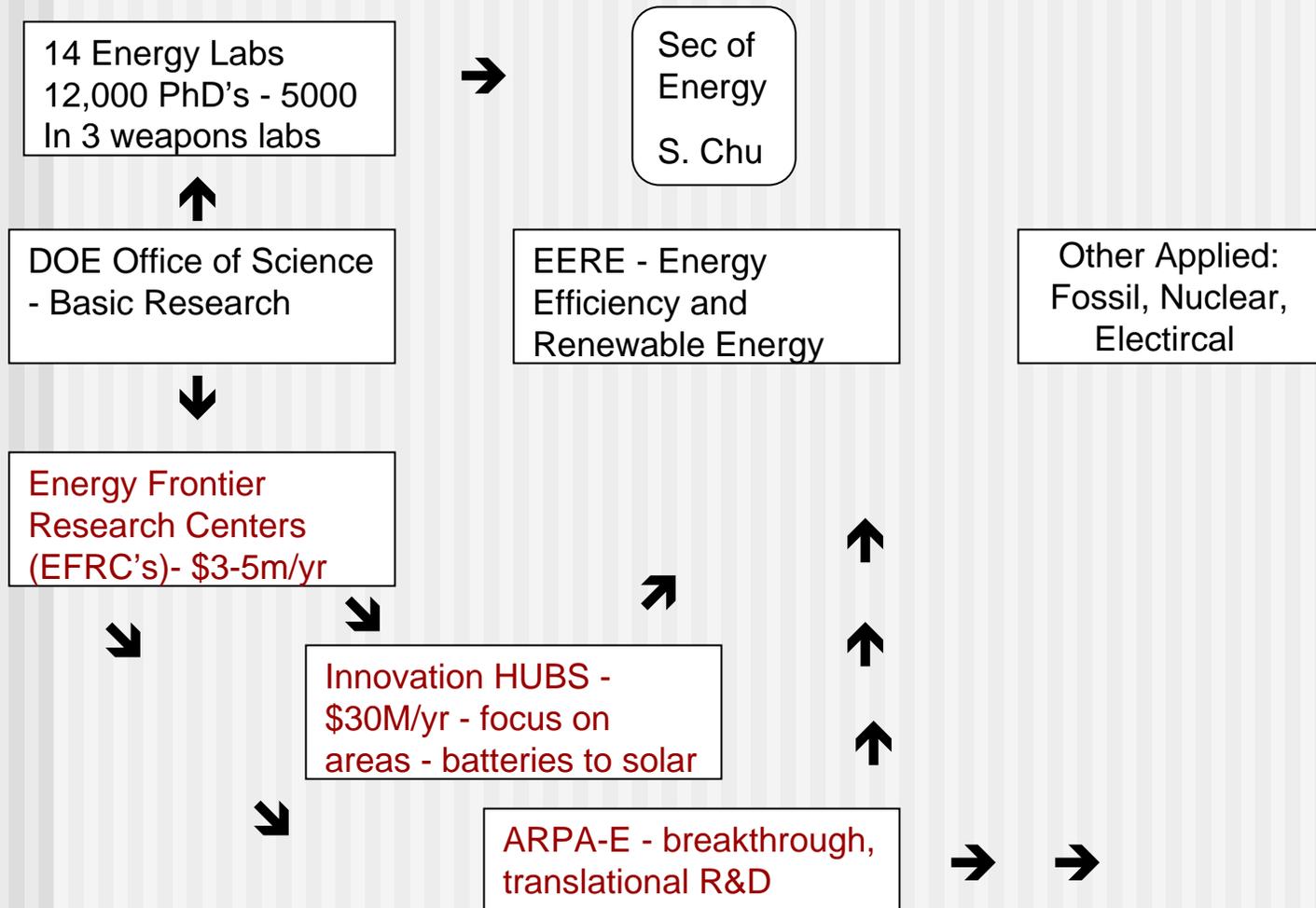
## -The Front End Problem:

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- DOE Sec Chu standing up **ARPA-E**
  - Will the labs/DOE agencies allow it?
  - Has \$400m in Stimulus funding appropriated
  - Sec. Chu personally backs the model
  - 2 ex-DARPA staffers designed it
  - Will it get next \$300m in FY11 from Congress? Then Scale?
- The Other Pieces Chu seeks:
  - **Energy Frontier Research Centers (EFRC's)** - now 46 -
    - Effort to engage university base in energy research; \$3-5m/year
  - **Energy Innovation HUBS** - mini-Bell labs - in key areas: solar, batteries, advanced nuclear, building efficiency; \$20+m/year
  - **Re-energyze** - energy education; no revolution without trained troops
    - Administration focused on organizing a tech revolution in FY10 Stimulus
    - But Its Clean Tech Fund (\$150B/10 years) is failing; falling off a cliff?

# 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 - neglecting 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 most start-ups and small firms
    - Loan guarantees not useful unless you can get a loan
  - 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 tech list not a strategy and long way from Roadmap

# The Problem of Technology Neutrality

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- **Bills written backward**
  - Each technology has its 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
  - 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
  - Climate bill indef. delayed – political support not there
  - 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
- Where is the funding source?

# And: Need 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 test beds to financing to procurement to creating the initial market
- An energy transformation is at least as hard as IT
- We're going to need to operate at all the stages of the system
- DOD could play role in an energy innovation system through facilities and procurement – can be **test bed and initial market**
- **DOD actually wants to play: strategic and tactical concerns and efficiency/cost needs**

# As usual, we're going to need these guys...

## DOD's 20<sup>th</sup> Century

### Innovation Waves:

- Aviation
- Electronics
- Nuclear Power
- Space
- Computing
- The Internet

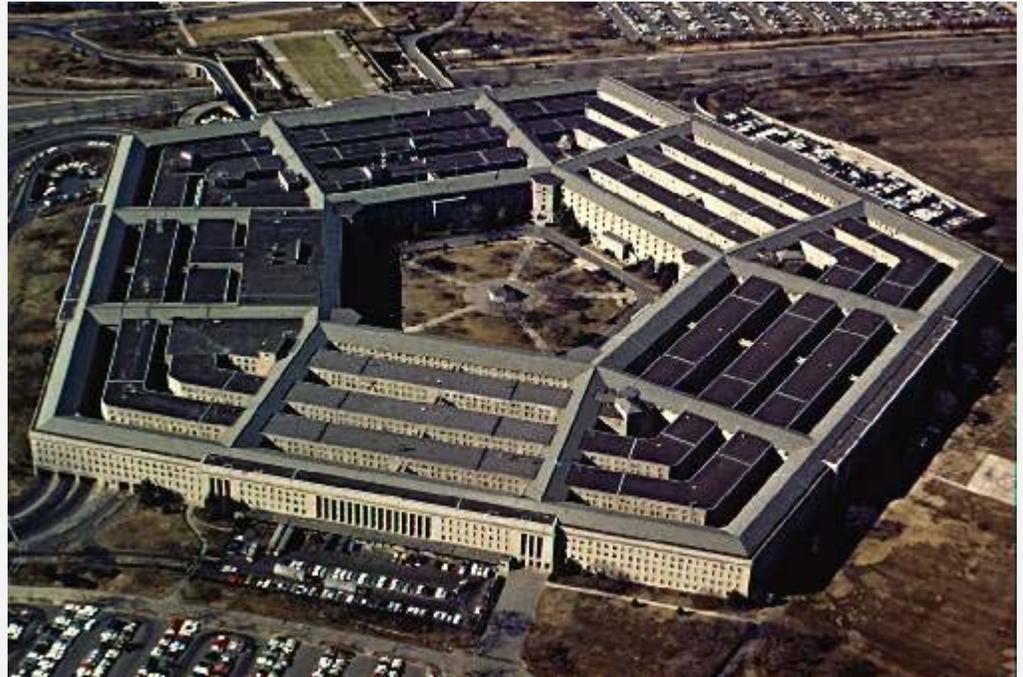


Image by [Chuck Holton](#) on Flickr.

# Where is the fallback plan?

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- For 15 years, since before the Kyoto Protocol, we have assumed that we would tackle climate issues through a carbon price
- We never developed a fallback plan
- Now we need one

# We will need “Plan B” for Climate

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## ■ *Elements:*

- Energy Security/Economic Competitiveness Rationale
- Strong technology strategy and support
- DOD test bed and initial market role
- EPA Clean Air Act regulatory authority
- Regional, state-based economic incentives and regulatory regimes for carbon
  - California, Northeast – regional markets
  - Electrification Coalition – “Denmark” sized pieces for transport electrification
- “Public Good” rationale – financing CCS, nuclear

# Plan B:

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- Carbon Price approach was based on traditional Neoclassical Economics
- Plan B will be based around Economic Growth/Innovation Economics
- Interesting test...

# Energy as an Economic Wave:

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- Energy - Next technology revolution?
  - Could it be new tech *innovation wave*, drive efficiency throughout the economy?
  - If you can get an energy tech revolution into innovation wave status, it goes on autopilot

# But: What are others up to?

## Wave Leadership Not Assured

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### ■ China

- \$400B/10 year clean energy tech program- ACORE
- \$3/watt subsidy for solar - largest in world; 10X nuclear
- 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 - 10x nuclear

- 2020 target for solar: 20GW's (sources: NYT, Wash Post)

# RECAP – Class Four:

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- *Bonvillian & Weiss (“Covered Wagons” article)*
  - *4 step process for innovation – look at the launch system and build incentives to fit*
- *B&W, con’t - Gap filling*
  - – look at the energy innovation system, identify the gaps, and fill them
  - DOE gaps: frontend: breakthrough translational research;
  - Backend: bank/financing; technology roadmapping
  - Could DOD supply testbeds, initial markets?

# RECAP, Class Four, Con't

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- *Deutch* – Wholly-owned Gov't Corp. model
- *Alic, et al* – DOD systems role in energy innovation
- *DOD testimony (Robyn)* – DOD as testbed and initial market
- *Bonvillian – Plan B for Climate: DOE* –
  - Progress on the Innovation Front End
  - Need to look at the Back End
- Could we prepare a Plan B for climate?
- Could we create an innovation wave?

MIT OpenCourseWare  
<http://ocw.mit.edu>

Resource: Science Policy Bootcamp  
William Bonvillian

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