Class Ten: The Challenge of Energy Technology

"Innovation Systems for Science, Technology, Mfg., Energy and Health"

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William B. Bonvillian

MIT

RECAP ---

Key points from Classes 1-9

Summary from Class One – Innovation Economics:

- **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 Two

- **NELSON:**
  - Idea of innovation as a <u>complex system</u>
  - Operates at a <u>national scale</u>
  - Can do <u>comparative analysis of national innovation systems</u>
  - System operates at the <u>INSTITUTIONAL LEVEL</u> -look a connections, interaction between <u>innovation actors</u> in public and private sectors
- **INDIRECT INNOVATION FACTORS, TOO**
  - Mix of indirect and direct innovation factors in interacting in an innovation ecosystem
- **ATKINSON –** innovation wave theory
- **SCHULTZ** – beware industrial policy

Classes Three through Five:

- <u>Classes 3 & 4: Case Studies -</u>
  - <u>manufacturing</u>– the crucial role of production in innovation
- <u>Class 5: Innovation Organization</u>
  - <u>Associationalist model</u>; public private partnership
  - Vs. Conservative model
  - Vs. Nat'l Security model
  - <u>Innovation</u> - look at at <u>the institutional and personal levels</u>
  - <u>Institutional level - after WW2, V. Bush splits R from D</u>
  - <u>Stokes</u> – US: Disconnected model - creates tech transition problem

Class Six:

Class 6:

- **How to cross the "Valley of Death" (Branscomb/Auerswald)?**
- **Associationalist programs of 80's, 90's**
- **"Is war necessary for economic growth?" – Ruttan**
- **In-Q-Tel – the most radical, interventionist model – gov't VC "picking winners and losers"**

Class Seven:

- Class 7 - Organization of Innovation at the Face to <u>Face Level</u> -
  - Innovation is people - not institutions
  - <u>Great Group theory</u>
  - Great group rule-sets: flat collaborative non-hierarchial, mix of disciplines, room for leadership
  - The <u>Third Direct Innovation Factor: Innovation Organization</u>

Class Eight:

- **Class 8 - DARPA as renewal of the WW2 connected model**
  - **Combines institutional connectedness and sponsors great groups**
  - **Operates at both levels of innovation – institutional and personal**
  - **Role of Technology Visioning (Carleton)**

Class Nine:

- Class 9: Applying the Innovation Framework – NIH
  - A disconnected model – 27 Institutes and Centers – not cross-cutting
    - Basic research model, non interdisciplinary
  - Pending 3rd Revolution – convergence – can it adopt?
  - Institutional stovepipes vs. connectedness
  - Can NIH sponsor great groups – then: ability to scale?

Now – Class Ten – The Energy Technology Challenge

- Case study for what we have learned so far – but: *new* – complex established "legacy" 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)*

- 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_2 emissions that would otherwise be released.

Socolow & Pacala, Con't

- 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

- “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” – Socolow and Pacala

Bonvillian and Weiss, Taking Covered Wagons East (*Innovations*, MIT Press 2009)

- 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 <u>technology policy</u>
    - Overlap: some agreement on new energy technologies
- Few new energy technologies technological and economically ready for implementation
  - Policy consensus on need for new technologies, but few detailed attempts on how to implement them

Scale and Price Issues in Energy

- New energy technologies must land in a complex, established sector
  - A “techno-economic-political paradigm”
- Private sector R&D discourage by wild price osvillations in energy prices
  - Oil \$20/barrel 1998, \$140/barrel 2008, ~\$35/b 2016
- Public sector - 40 years of R&D yet few technologies have transitioned
- Need for parallel and supporting policies on price and on technology supply

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

The Underlying Innovation Dynamics Models: Pipeline, Induced, Extended Pipeline, Mfg.-Led, and Innovation Organization

- Energy requires new unified theory of innovation
- Model: 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 Innovation Dynamics, Con't

- Model : 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
- Note: "Extended Pipeline" and "Manufacturing Led" Innovation Models

The Innovation Dynamics, con't

- Model: Innovation Organization Model
  - 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 four models**
    - Unlike IT, which was essentially tech push from DOD
  - **Energy will require filling innovation institutional gaps**

Summary – so far

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

Next issue:
Scaling Energy Innovations

- **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)

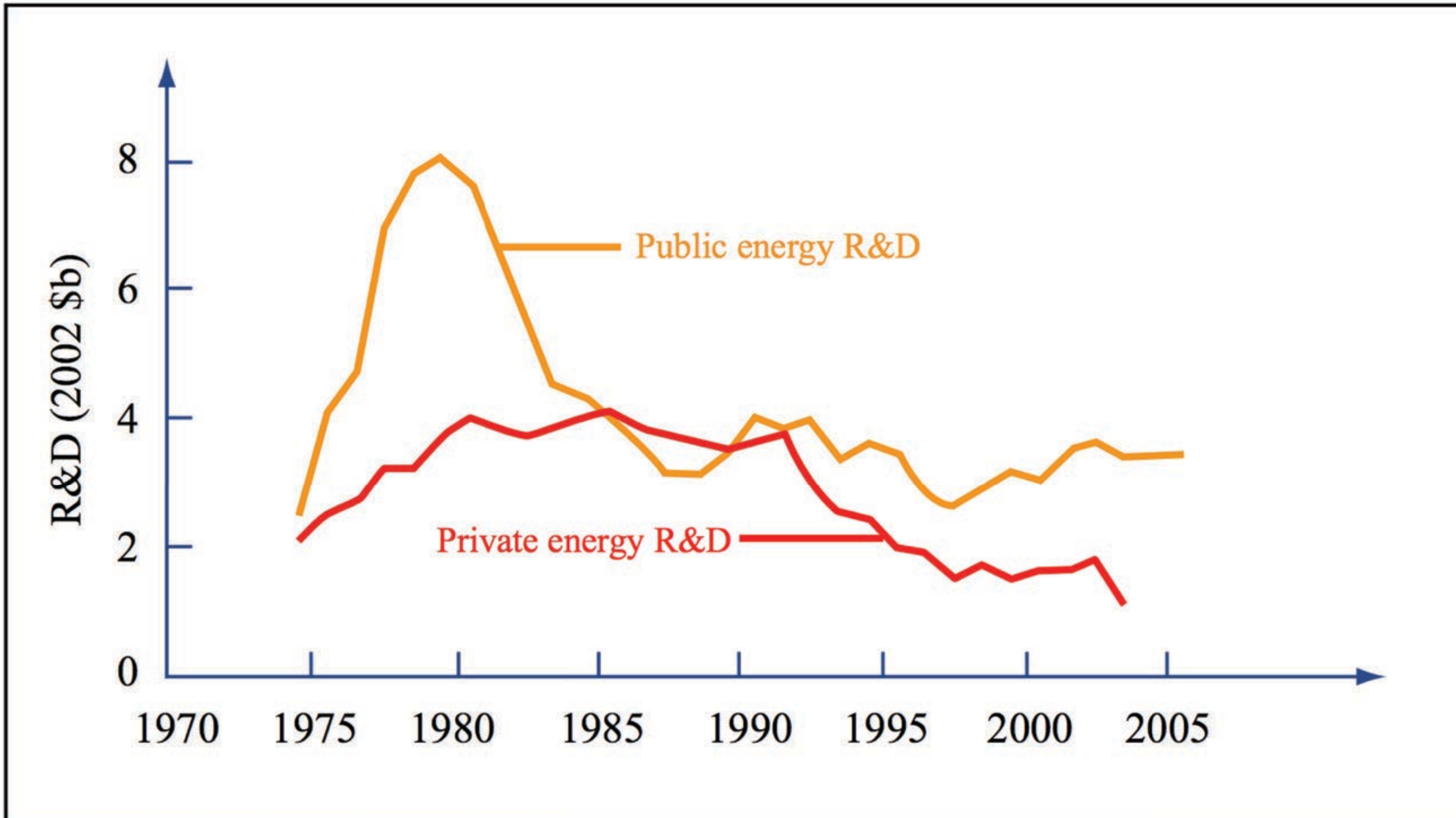

Figure by MIT OpenCourseWare.

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

<u>Innovating industries</u> -

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

<u>Established industries</u>:

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

- <u>Average R&D/ann.rev., all US industry</u>: 2.6%
- <u>Private Energy Sector</u>: 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

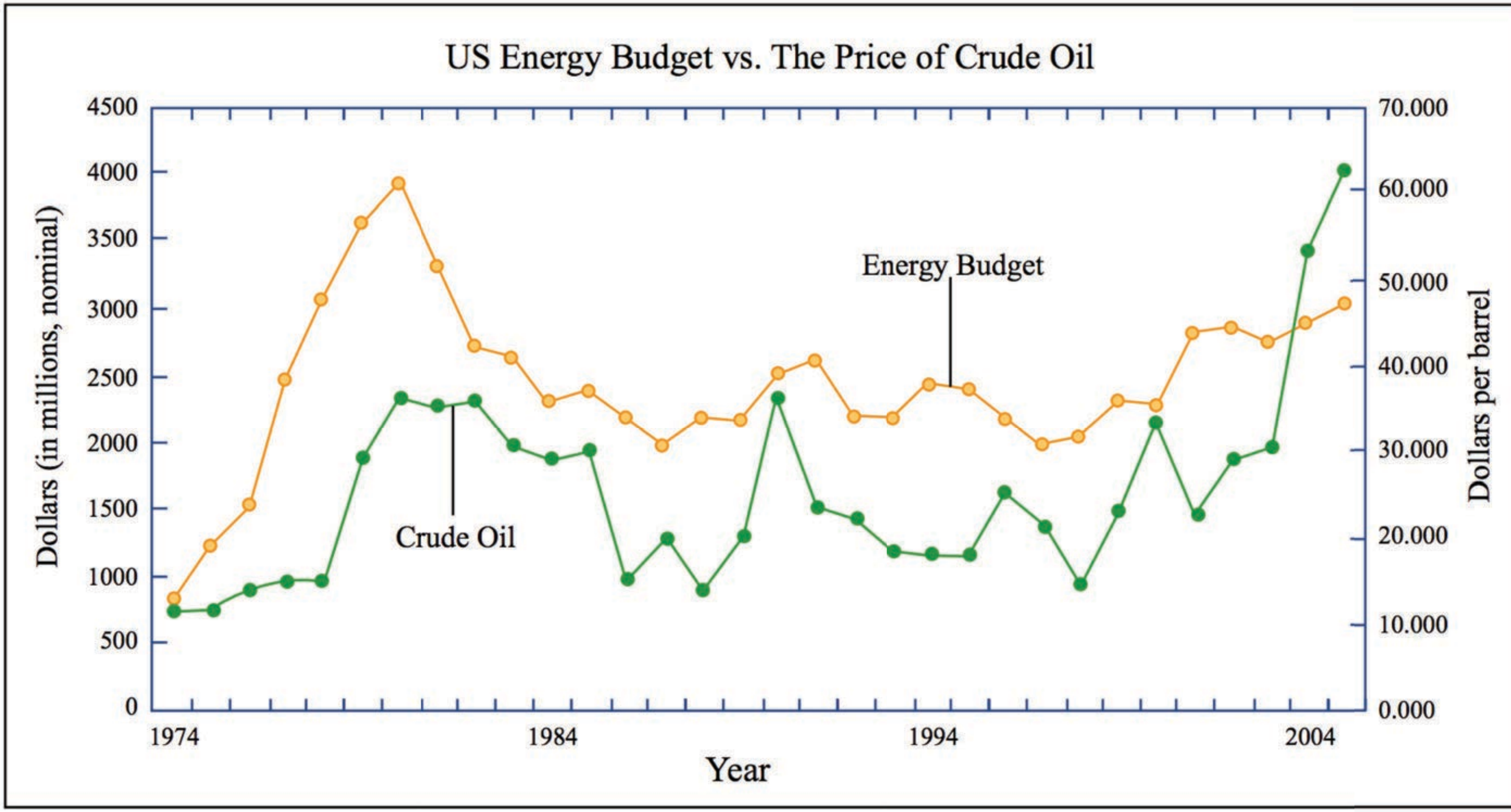

Figure by MIT OpenCourseWare.

-- 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

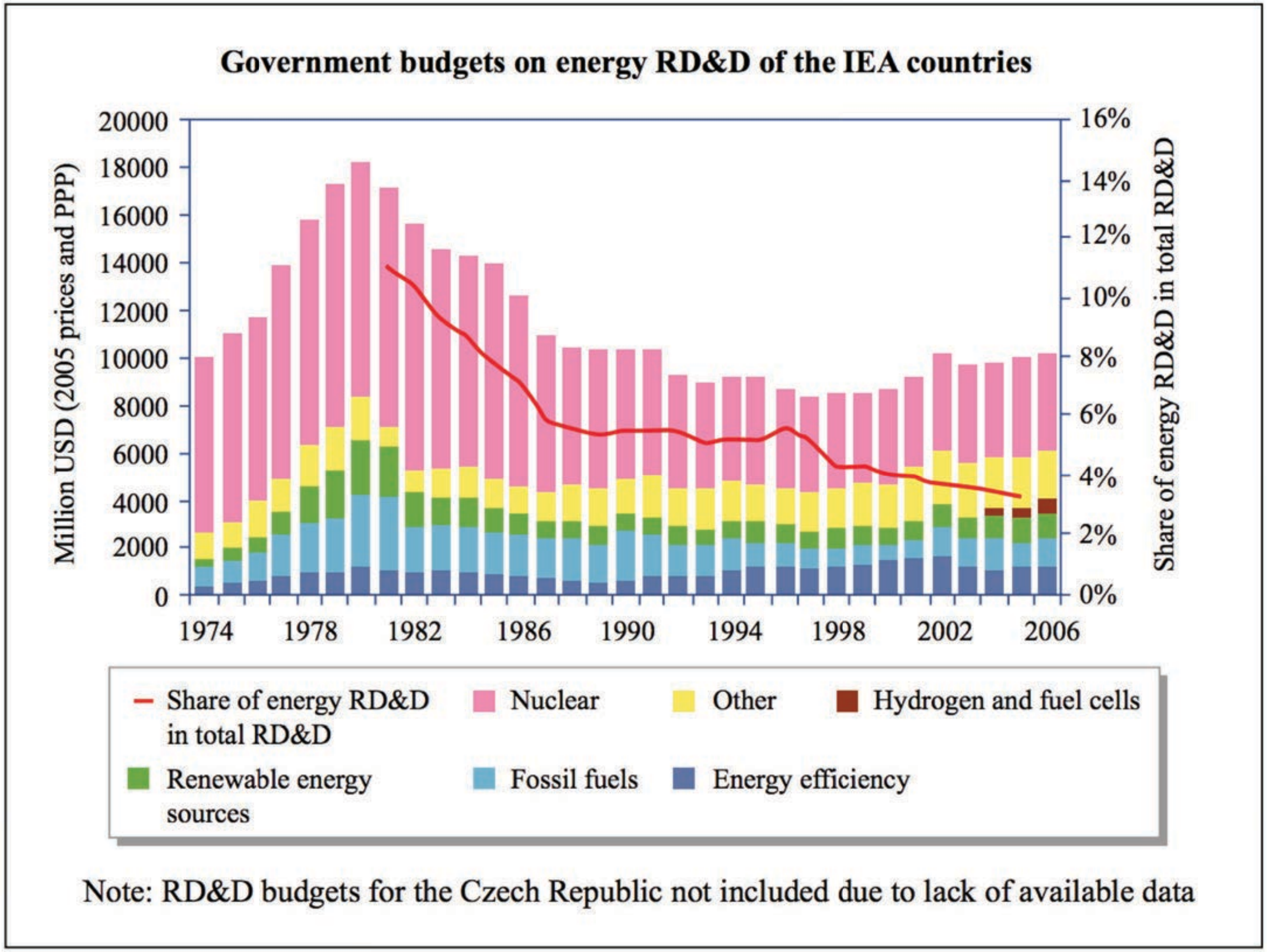

Image by MIT OpenCourseWare.

Source: IEA 2007a, OECD 2007a.

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 <u>much</u> more complicated proposition

Because the US is a Covered Wagon Culture

Image is in the public domain.

- 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-Social Paradigm*
- Alternative technologies are evolving
- Must be <u>price competitive immediately</u> 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 useful but is unlikely for some time…

- A price on CO_2 captures externalities
- Sends an unmistakable <u>price signal</u> to energy users
- <u>Enables new entrants to enter and start to drive down the cost curve</u>
- Only works if it is sustained and high enough
- But: politically unlikely in the U.S. anytime soon

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
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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

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

Step One: Identify Technology 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

Bonvillian and Weiss, Steps – Con’t

- 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 END

  in 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

- **“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?

- 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"

- 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
- <u>Consumers will pay a premium for first generation of new functionality</u> products
- But <u>first gen of new energy won't offer much new functionality</u>
- Could R&D focus on driving down price as well as research? – ARPA-E doing

Summary – Bonvillian & Weiss

- Need to apply all innovation models:
  - Pipeline; Induced; Extended Pipeline; Manufacturing-Led; Innovation Organization
- 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

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

- 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

- 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

- 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.
- **BUT: Sequestration limiting this**

Robyn – presents "Backend" ideas

- Robyn – DOD as testbed and initial market
- These are: Backend ideas
- ***<u>Where are we on the Front and Backend?</u>***

Bonvillian, "Applying Innovation Policy to the U.S. Energy/Climate Challenge" (Chapter, Edinburgh Univ Press 2016 book)

- Cap and Trade – has a structural problem – it' s neoclassical economics, therefore it' s not focused on innovation policy
- It's an economy-wide fix, but we're not ready politically because energy tech sectors not economically or technology ready
- Can there be a plan B – series of policy bricks not a single fix?

The Institutional Problems with Energy Innovation System

-The Front End Problem:

- DOE Sec Chu stood up ARPA-E
  - The labs/DOE agencies are working with it
  - Had $400m in Stimulus funding appropriated
  - Sec. Chu personally backed the model
  - 2 ex-DARPA staffers designed it
  - ~$300m a year from Congress

- The Other Pieces :
  - 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
  - Tech Transition Office – move technology better out of labs, DOE
  - Advanced Manufacturing Office and Institutes – EERE – drive down production costs for new technologies
  - Cyclotron Road – outside LBL – tech trans. by "outside-in"

Front End of DOE's Evolving Innovation System:

R > D> Applied> Demo> Implement

BUT: What Will be curtailed By the Trump Admin.?

14 Energy Labs
12,000 PhD's - 5000
In 3 weapons labs

Sec of Energy

DOE Office of Science - Basic Research

EERE - Energy Efficiency and Renewable Energy

Other Applied: Fossil, Nuclear, Electircal

Energy Frontier Research Centers (EFRC's)- $3-5m/yr

EERE – Advanced Mfg.Office, Adv'd.Mfg. Inst's, Cyclotron Rd.

Innovation HUBS - $20M/yr - focus on areas - batteries to solar

Technology Transition Office

ARPA-E - breakthrough, translational R&D

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**
    - Loan guarantee program limited with Solyndra bankruptcy Useful: **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 technology list not strategy or Roadmap
  - **But: will sequestration curtail tech strategy?**

The Problem of Technology Neutrality

- 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
  - 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, <u>Stimulus provided major new R&D funding input for FY10-12, then stagnation since 2013</u>
    - US deficit/fiscal posture/sequestration ongoing problem
- <u>Cap and Trade only significant possible new revenue source</u>
    - FY2010 President's Budget $150B "Clean Energy Tech Fund" from cap and trade revenues –
    - Climate bill indef. delayed – political support not there
    - Funding went fall off a funding cliff in FY13 and lost momentum – sequestration is major barrier
- Dec. 2015 tax bill did extend renewables credits
- <u>Paris – U.S. and OECD pledged to double R&D</u>
    - <u>Where is the funding source?</u>
    - <u>And - Will the U.S. stay in the agreement?</u>

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…

<u>DOD's 20th Century Innovation Waves:</u>

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

Where is the fallback plan?

- 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
  - Could it be technology-strategy oriented?

We will need “Plan B” for Climate

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

Summary -
- Plan B for Energy/Climate:

- Carbon Price approach was based on traditional Neoclassical Economics –
  - Economy wide - politically problematic
- Plan B will be based around growth economics/innovation policy and other regulatory and state elements -- not a pricing strategy
- Interesting test…

Bonvillian & VanAtta – ARPA:E Applying the DARPA Model to Energy (J.Tech.Trans. 2012)

A) ARPA-E has incorporated the DARPA mode

- flat, non-hierarchical
- program managers are "empowered,"
- project approval process is streamlined
- "right-left" research model
- challenge-based
- revolutionary breakthroughs
- world-class talent – experience in both academic research and in industry
- waiver of civil service hiring authority
- the project duration yardstick is the life of the PM
- "other transactions authority"
- "hybrid" model
- island/bridge model

New Elements at ARPA-E

- *Forcing Mechanism: Energy challenge different*
  - *differs from DARPA challenges – complex, established "legacy" sector (CELS) – needs new rules*

1) <u>Sharpening Research Visioning, Selection, Support:</u>

- <u>"White Space" of tech opportunities</u>
  - breakthrough areas where work not being done
- <u>Two-stage selection process</u>
  - Applicant feedback opportunity – sharpens reviews
- <u>Empowered Program Manager Culture</u>
  - "religion" – push their technologies to implementation
- <u>Fellows Program</u>
  - Intergenerational contact and mentoring dynamic
  - Considering: "technology wisemen"

New Elements at ARPA-E, Con't:

- Portfolio Approach
  - Range of risk in tech thrusts
- "Hands-on" relations with awardees
  - Help awardees with tech transition, co. connections

2) Building a Support Community:

- Have to get political support model right as well as substantive model
- Building internal connections within DOE
  - Off. of Sci., applied agencies, labs need to view it as their supporter not contender for funding
- Summit
  - Community for its award losers, connect to VCs, co's
- Support Community
  - VCs, co's., univ's starting

New Elements at ARPA-E, Con't:

3) Technology Implementation:

- Consider the implementation process during award and research processes
- Use "In-reach" within DOE
  - Conscious ties applied DOE agencies to move technologies to next stage
- Ties to DOD for testbeds and initial markets
- Commercialization team within ARPA-E
- Use "Halo Effect"
  - Conscious ties to VC's and co's

New Elements at ARPA-E, Con't:

- Connecting to the Industry Stage Gate Process
  - Industry R&D weeding out process very different from ARPA-E/DARPA which place tech visioning up front
  - But ARPA-E technologies must connect to stage gate
- Encourage consortia within sectors
  - Tie researchers to groups of co's for common learning and implementation
- Prize authority
  - being considered - has authority

Relevance of Add'l DARPA Features to ARPA-E

- As ARPA-E matures and starts to move its technologies to implementation, DARPA offers additional lessons…
- <u>Multigenerational technology thrust</u>
  - How to handoff between generations of PMs to maintain sectors of advance over time
- <u>Strategic Relations between Technologies</u>
  - Move related technologies that reinforce each other – storage and grid and renewables
- <u>Confluence with an Advocate Community</u>
  - Keep building community of researchers, co's, PM grads

Relevance of Add'l DARPA Features to ARPA-E, Con't:

- <u>Connection to Larger Innovation Elements</u>
  - ARPA-E working on this – needs to expand
- <u>Takes on Incumbents</u>
  - Because of Energy CELS problem, deep problem for ARPA-E – lessons from DARPA IT on how to do
- <u>First Adopter/Initial Market Role</u>
  - ARPA-E must do; connect to DOD for testbeds, procurement
- <u>Ties to Technology Leadership</u>
  - ARPA-E using ties to DOE Sec. Chu, CFO Isakowitz, and House Sci. Comm. ex-chair Bart Gordon
  - Has non-FACA industry advisors, too
  - Need to expand

The Remaining Technology Implementation Challenge for both DARPA and ARPA-E

- Tech implementation challenge will get harder for DARPA
  - Defense procurement in decline and stretching out so harder to land advances in DOD platforms
- Already hard for ARPA-E
  - CELS problem in energy is a major hurdle
    - VC's pulling out (standup takes too long in energy for their 3/5 year model), China provinces offering low cost financing
    - Whole implementation process in energy is broken
- Both agencies will need to focus more on the innovation system "back end" for implementation

Bonvillian, Addressing the Scaleup Challenge for "Hard" Technology Startups, *Annals of Science and Technology Policy,* v.1, no.1 (March 2017)

- U.S. relies on entrepreneurial startups to bring innovation into its system
- Developed a $60B/year Venture Capital support system to support startups

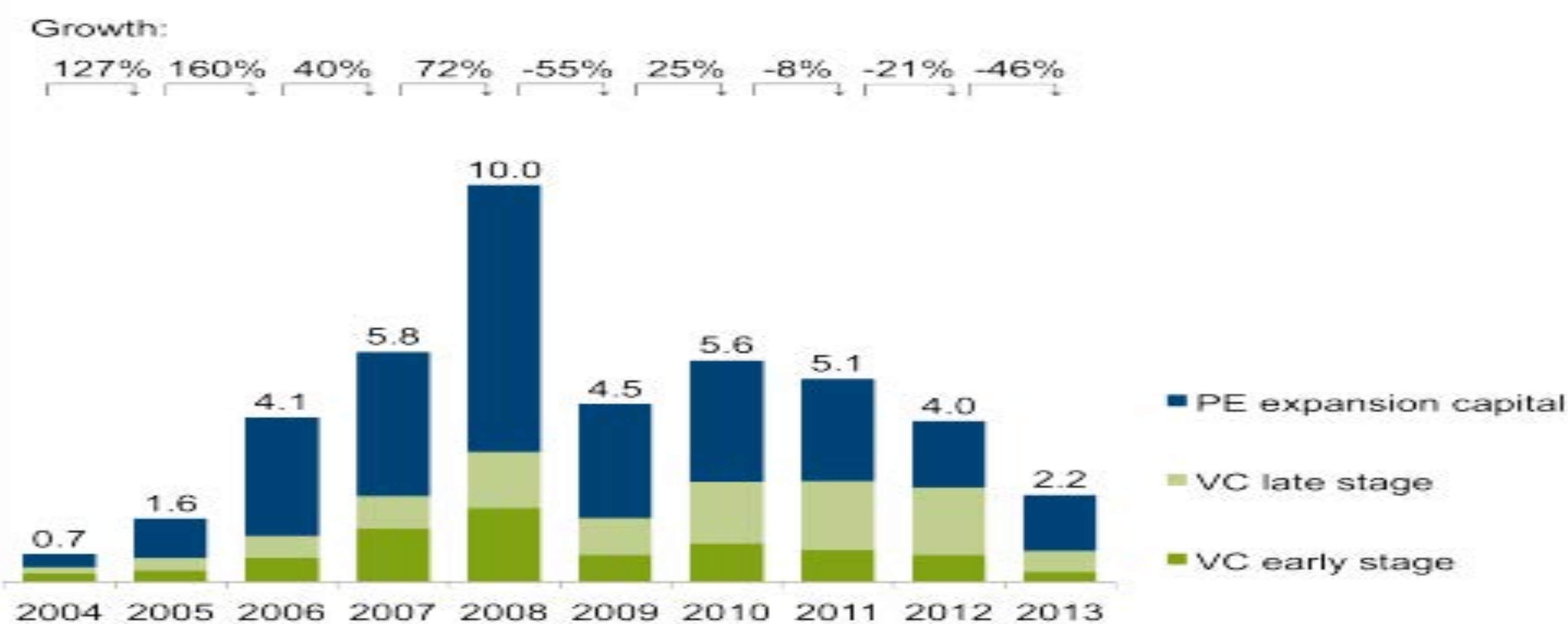
VC doesn't support Startups landing in "Legacy Sectors"

- **Most technologies land in complex established *Legacy Sectors***
  - **80% of the US economy**
  - **Initial technologies introduce limited new functionality**
  - **Compete against established technologies**
  - **Must compete on price on day one–no time to drive down cost curve**

- **Legacy sectors: *well-defended castles***
  - **Protected by *technological-economic-political-social paradigms***
- **Need startups to bring new technologies to Legacy sectors**
  - **Like: new energy technologies**

VC's don't like Legacy Sectors: Decline in VC Investment in Energy Startups

FIGURE 48. VC/PE NEW INVESTMENT IN RENEWABLE ENERGY BY STAGE, 2004-2013, $BN



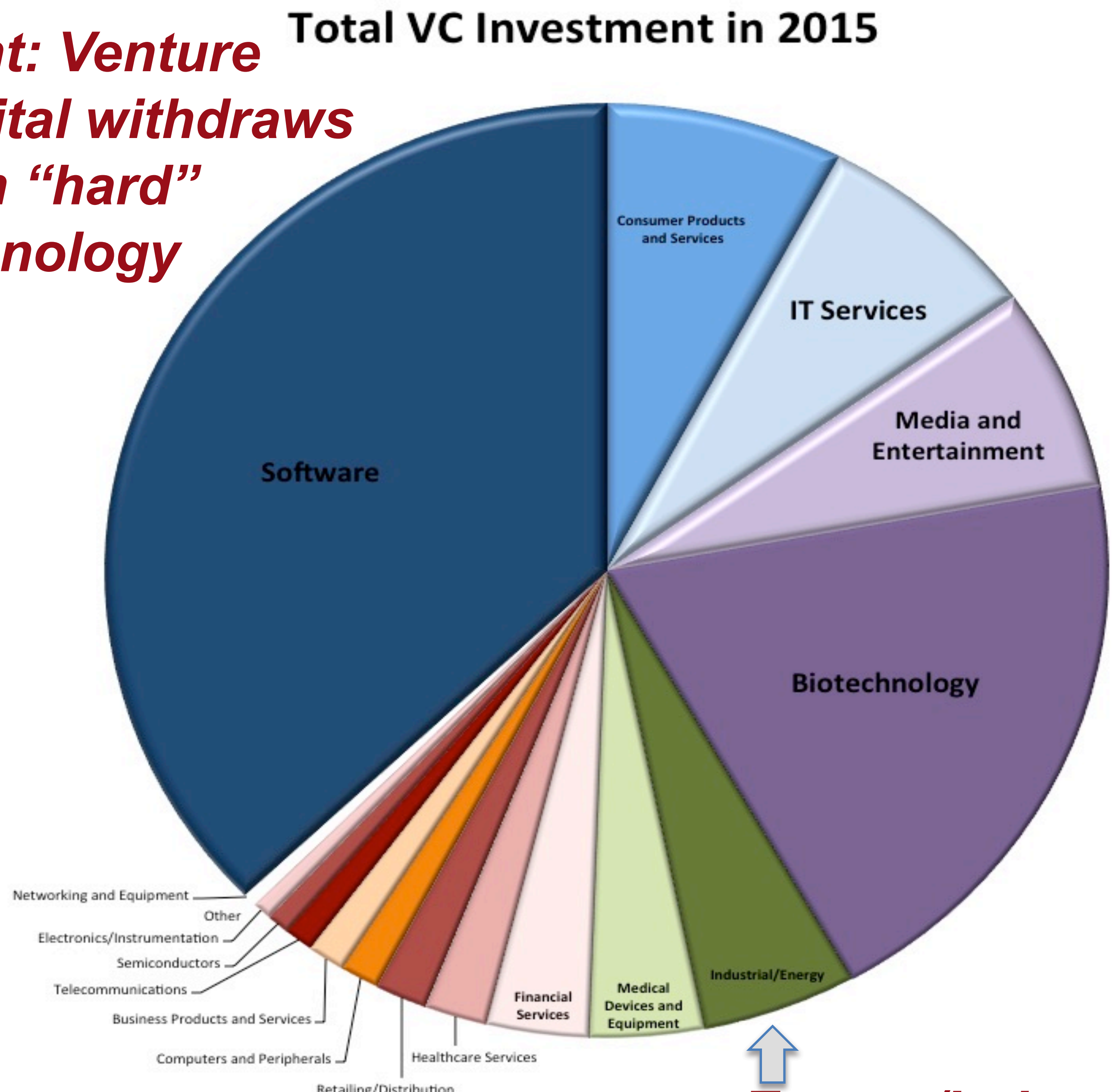
Buy-outs are not included as new investment. Total values include estimates for undisclosed deals

Source: Bloomberg New Energy Finance, UNEP

Non-IT Technologies: higher risk/ lower return so no VC

- From 2004-2008 VC new energy investment grew from $1B to $5B (47%/year)
- Then: After 2008: down to $1B/year
  - Energy: high risk, low return <u>vs</u>. software low risk, high return
  - 2006-2011: $25B in clean tech VC $; less than half returned
    - (B. Gaddy, et al, “Venture Capital and Cleantech”)

Point: Venture Capital withdraws from "hard" technology



Energy/Industrial = 5%

From Advanced Manufacturing – The New American Innovation Policies. Courtesy of MIT Press. Used with Permission.

“Innovation Orchards”

- Rafael Reif, MIT - ***substitute space for capital***
- *Innovation Orchards*”
  - Already rich innovation cluster in Boston, but scale-up issue
  - Need: technology and equipment rich space for startups
  - full of know-how – use regional support to build
- for: *advanced prototyping, demonstration, testing - perhaps small lot pilot production*
- Gets startup down scale-up curve
- De-risking – get them into range of more traditional financing
- ***Could accelerate the innovation – better than VC fix***

Example: Cyclotron Road/LBL

cyclotronroad

- IDEA: Park a bunch of energy tech startups (16) outside fence of Lawrence Berkeley Lab in intermediary space
- Pay them salaries
- Give them the keys – let them invade
- Access to advanced technology, equipment, know-how
- New tech transition model:
  - *Old model* – inside/out - get the labs to transition their own technologies
  - *New Model* – outside/in
- Better model? More DOE labs will do

Example: TechBridge

- **TechBridge – arm of Boston Fraunhofer for energy startups**
- **TechBridge Role:** *Prototype, Pilot Production, Test, Validate*
- Link startups with *industry partners*, **then prototype. test and validate technology for production –**
  - **use** Fraunhofer facilities for test/validation**,**
  - **use industry partner who wants the innovation for scaleup**
- **So** high grade industry level tech validation w/ scaling **with partner – Validation is key**

Example, MIT's The Engine

- **Some Univ's have incubators** – tend to be early stage, business plan development
- But: for hard technologies, tech scale up is the challenge – The Engine's role – **adv'd prototype, demo, testing, pilot production**
- Issue: "**grad school" for hard tech** startups – draw from area incubators
- **Access to MIT facilities** – don't lose your ID card when you graduate – treat startup grads as part of the family
- 6 startups in residence now, for **2 years** (too short?), can be many more in **non-residence support status**
- **Bridge funding** – MIT $25m, want $100m
- **Blend Cyclotron Road and TechBridge?**
- **Secondary Nodes** – like Lincoln Lab (famous adv'd prototyping capability) and Draper, but also area companies.

But what does a federal lab know about manufacturing?

- A federal lab knows technology research and equipment
  - But federal labs don't know about production?
- So: NEW IDEA – a missing feature for innovation orchards:
- Incubator Greentown Labs in Somerville joined Mass. Manufacturing Extension Program in 1 year pilot program
- Link scaleup ready startups with small manufacturers
- Don't have to go to the prototype shops in Shenzhen – can find capabilities in your own backyard

MassMEP
Manufacturing Extension Partnership
YOUR RESOURCE FOR MANUFACTURING GREATNESS

GREENTOWN LABS

GreentownLabs/ MassMEP

<u>*Here's what happened:*</u>

IDEA ***They need each other - startups need production, manufacturers don't do R&D, need innovation access***

- 46 startups a Greentown; 33 Startups were interested in linking to SME manufacturers from 7 different locations across eastern Mass.
- 83 Manufacturers were interested in working with and connected to Startups.
- 120 Connections were made between Startups and Manufacturers.
- People intensive effort – online matching won't work
- 10 Workshops held by Greentown Labs
- Over 100 office hours held at Greentown Labs
- 8 outside startup support networks expressed interest in learning from the Initiative
- 16 Partnerships were formed between Startups and local Manufacturers.
- Basic training for startups on production could go online and scale; but *personal relationship-building critical* – it's a marriage, love required
  - (sources: Micaelah Morrill, Greentown, Peter Rossi, MassMEP)

Wrap-up: Role of Policy in Startup Scaleup

- ***So:* innovation policy challenge:**
  - Need to **scaleup innovative startups** for production of new technologies
  - **But financial support for non-IT startups in sharp decline**
- **Are new policy models emerging to fix this?**
- **“Innovation Orchards” idea fits** – substitute space for capital
  - Rich technology, equipment, know-how space for startups
  - Help get them through advanced prototype, demo, testing, pilot production
  - **Cyclotron Road, TechBridge** provide working models
- **Another missing link: connect startups to small manufacturers**
  - Can link startup incubators to startups with MEPs -- in every state – **Greentown Labs/MassMEP** example
- **Can this work? Feds – no new money, can’t create new programs**
  - But these policy fixes are **already authorized, have low capital costs, better utilization of existing assets** – labs, MEPs

Energy as an Economic Wave:

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

RECAP – Class Ten:

Socolow and Pacala - wedges

Bonvillian & Weiss – Energy as Legacy Sector -

- *4 step process for innovation – look at the launch system and build incentives to fit*

- *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 Ten, Con't

- *DOD testimony (Robyn)*– DOD as testbed and initial market
- *Bonvillian – chapter - 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?
  - Carbon pricing strategy misses a tech strategy
- ARPA-E as a new model on the front end
- *Startup Scaleup (Bonvillian – Annals of S&T)*
  - VC financing gap for new technologies & new models
  - *Could we create an energy innovation wave?*