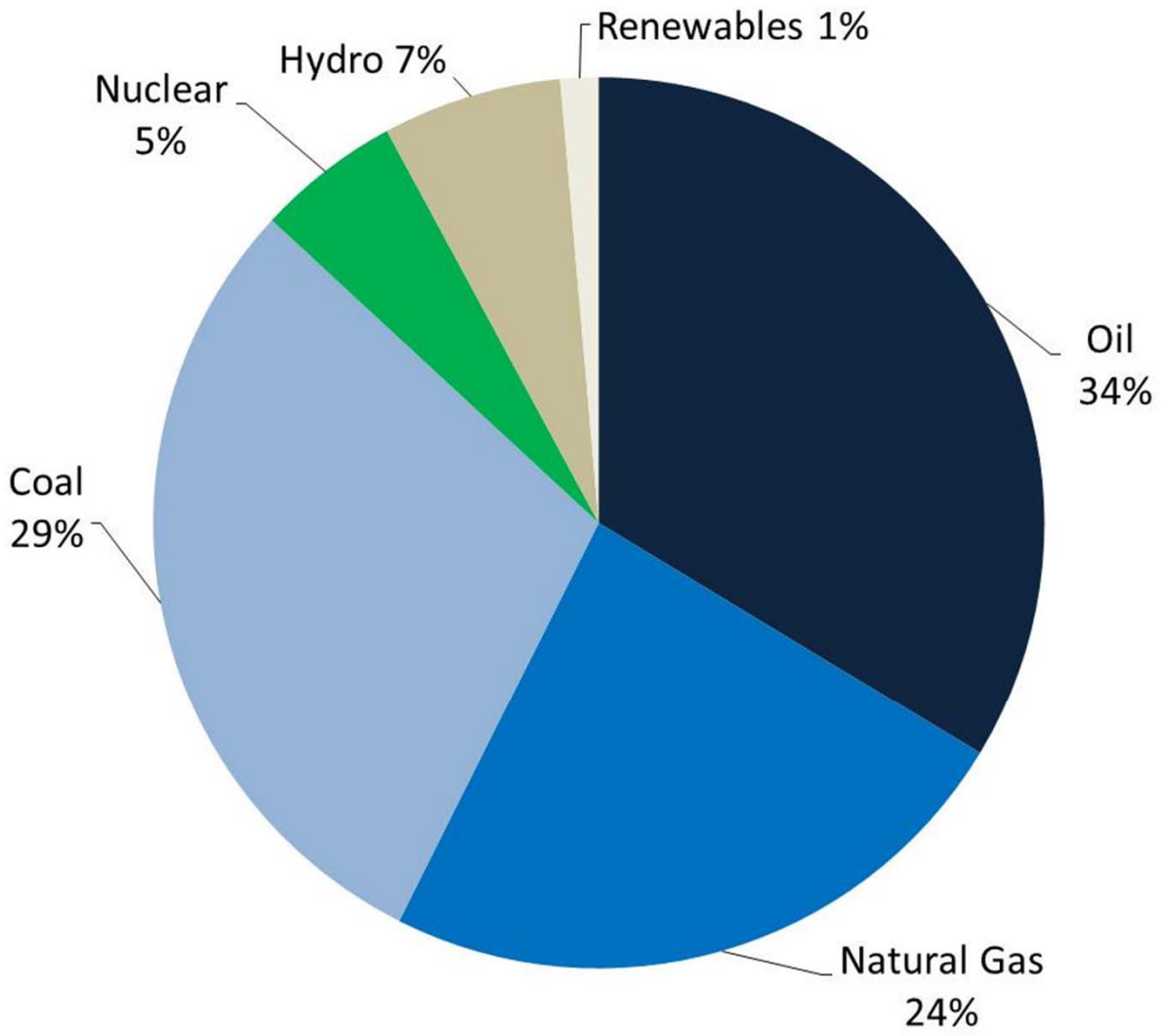
Innovation and Entrepreneurship in Clean Energy

Ramana Nanda, Ken Younge and Lee Fleming

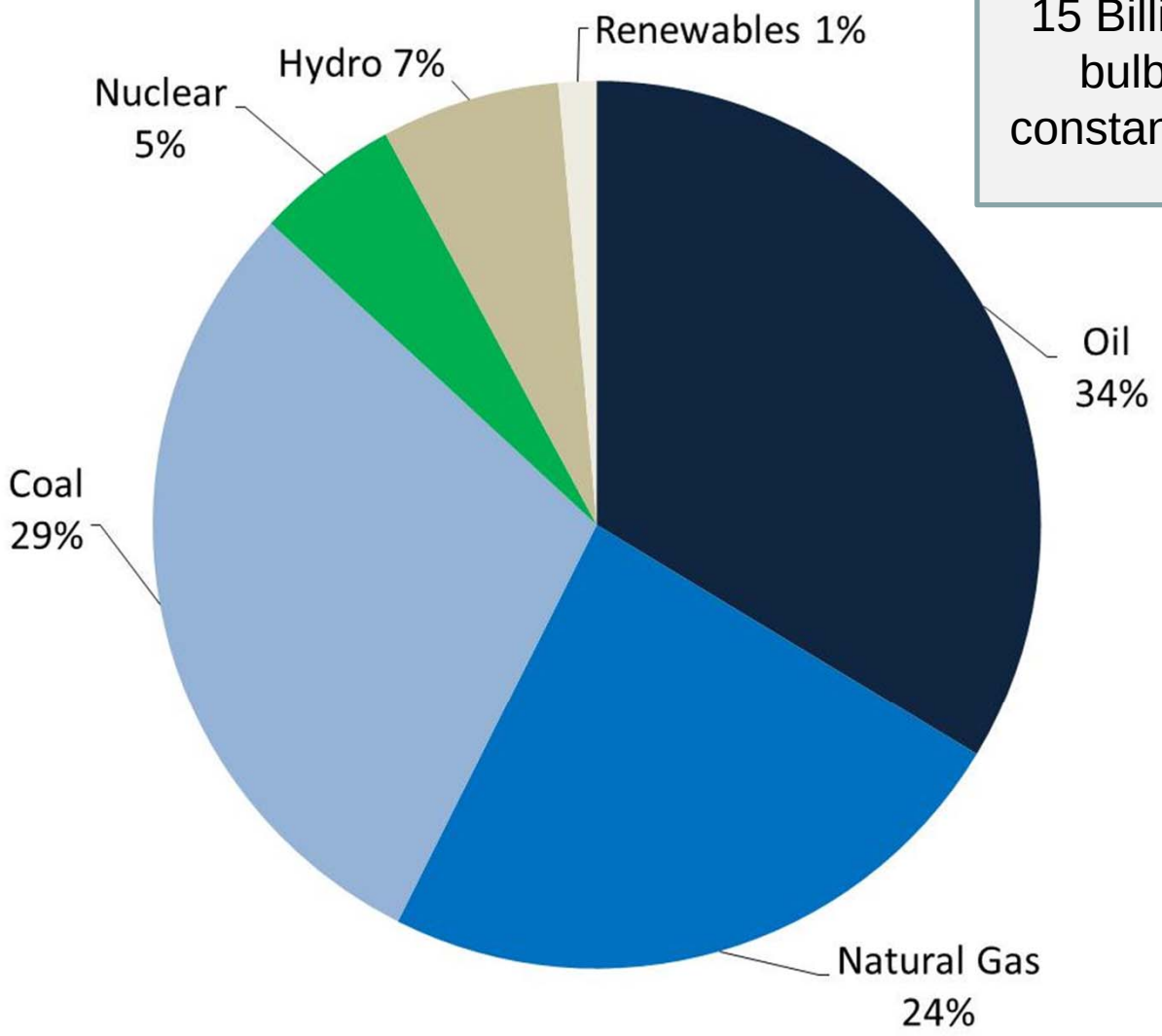
The Changing Frontier: Rethinking Science and Innovation Policy Pre-Conference

October 27, 2012

Source of Global Energy Consumed in 2010 (Total = 132,000 TWh)



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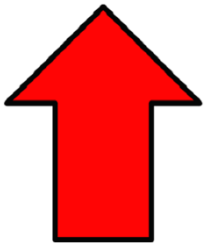
15 Billion 100 watt bulbs running constantly for 1 year

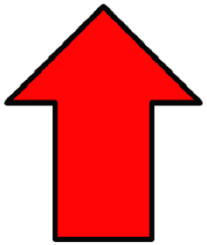
What drives the demand for energy?

Population X GDP per Capita X Energy demand per $ of output

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- Even if energy demand per $ of output remains stable, population growth and rising incomes across the developing world will drive massive growth in energy consumption
- Power required increased from 1 TW in 1945 to 15 TW in 2010
- Forecast to increase to 40 TW in 2050. This is equivalent to setting up 750 large coal burning power plants **per year** for 40 years

Need Radical Innovations in Clean Energy Production!

- Global Warming
- Pollution
- National Competitive Advantage
  - Similar to semiconductors, high tech, biotech

Little is known about Innovation in Clean Energy

- Where is the innovation taking place?
  - Startups / large incumbent firms / academia / Independent inventors?
- What is the geography of clean energy innovation
  - In the US and internationally?
- How are institutions and policies that facilitate the commercialization of these technologies impacting outcomes?

This Chapter

- Focus on renewable energy
  - Solar / Wind / Biofuels
- Leaves out “clean tech” focused on energy efficiency and storage
  - Smart Grid / Energy Efficiency Software, Batteries
- Leaves out cleaner sources of conventional energy
  - Natural Gas (cleaner than coal), Nuclear, Hydro, Geothermal

Objective

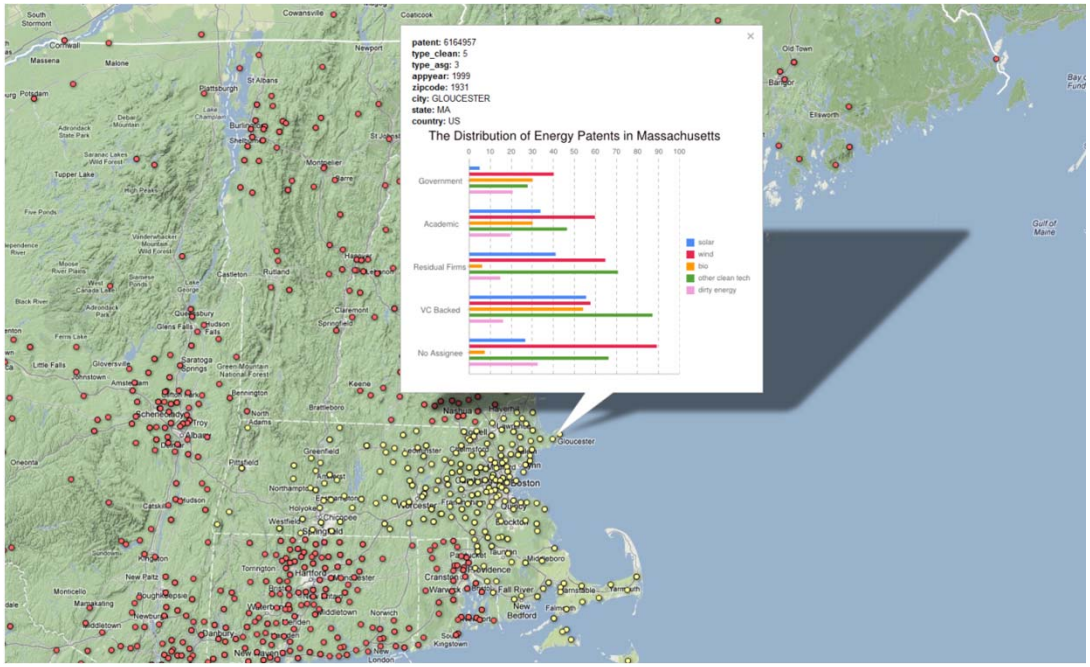
- Use patent data to characterize the nature of clean energy innovation
  - Organizational form (startup / incumbents)
  - Geography (across US / Internationally)
- Relate patterns to institutional factors that facilitate or hinder clean energy innovation
  - The challenge for venture capital in clean energy
  - Barriers to innovation by incumbents
- Discuss implications for innovation policy

Secondary Objective: Spillovers

- Develop a set of tools that can be of wide applicability to other researchers
  - Machine learning algorithm to define scope of technologies in patent database
  - Mapping tools to visualize geography of innovation

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Data Sources

- IP Checkups (1995-2009)
  - Focused on USPTO data, but looking to expand to other patent offices
  - Working to supplement this by using it as a “training set” for machine learning algorithm on the full USPTO database
- Cleantech i3 (2000-2012)
  - Most comprehensive source of VC backed startups in Clean Tech
  - Focus on first institutional financing event
- Bloomberg New Energy Finance (2000-2012)
  - Data on Venture Capital backed startups as well as locating of manufacturing plants for solar panels and wind turbines

Patent Sample Breakdown

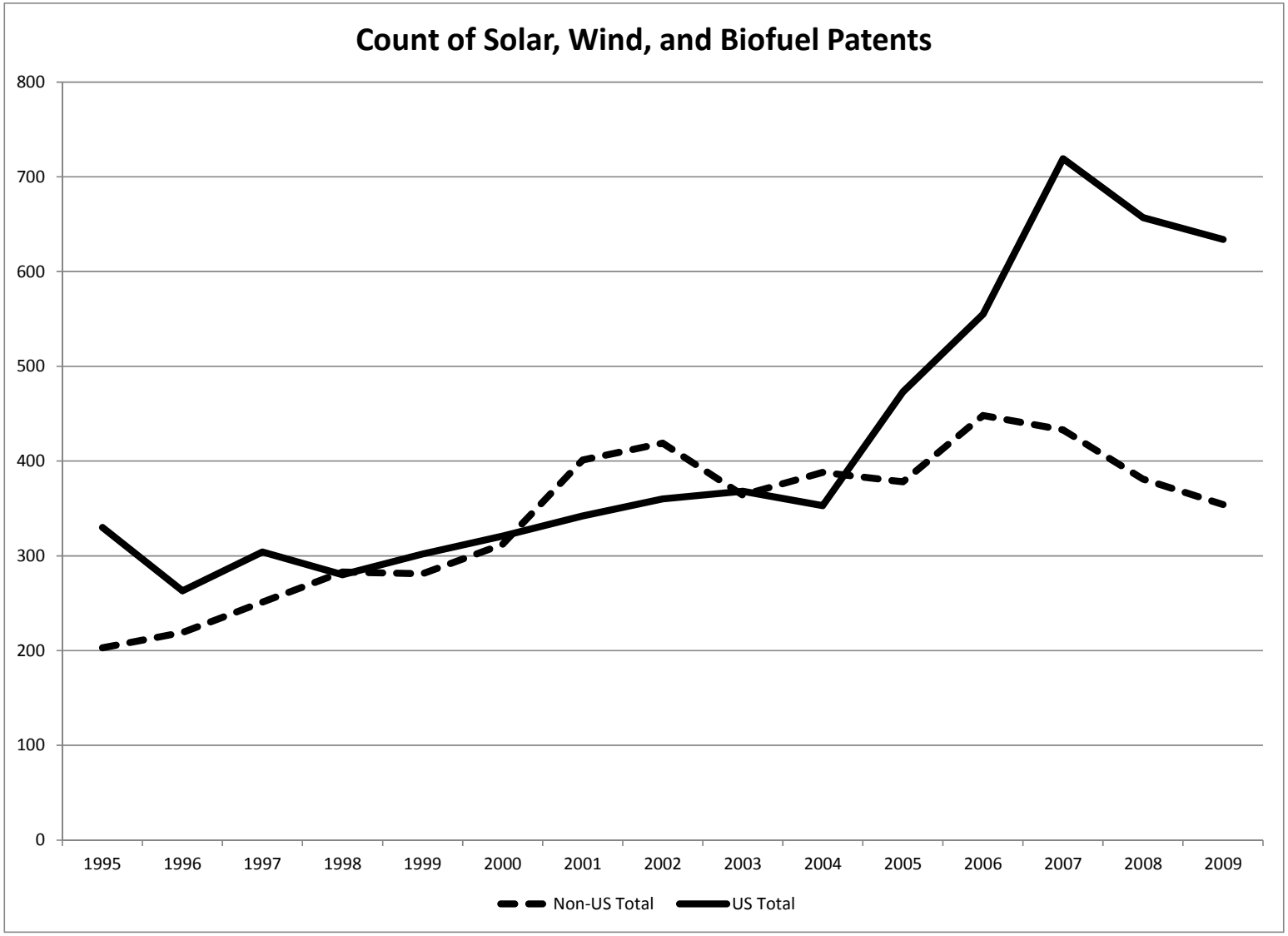
	VC-backed	University & Government	Residual with Assignees	No assignees	Total
Solar	399	368	3,219	929	4,915
Wind	258	42	1,255	668	2,223
Biofuels	141	523	3,160	414	4,238
Total	798	933	7,634	2,011	11,376

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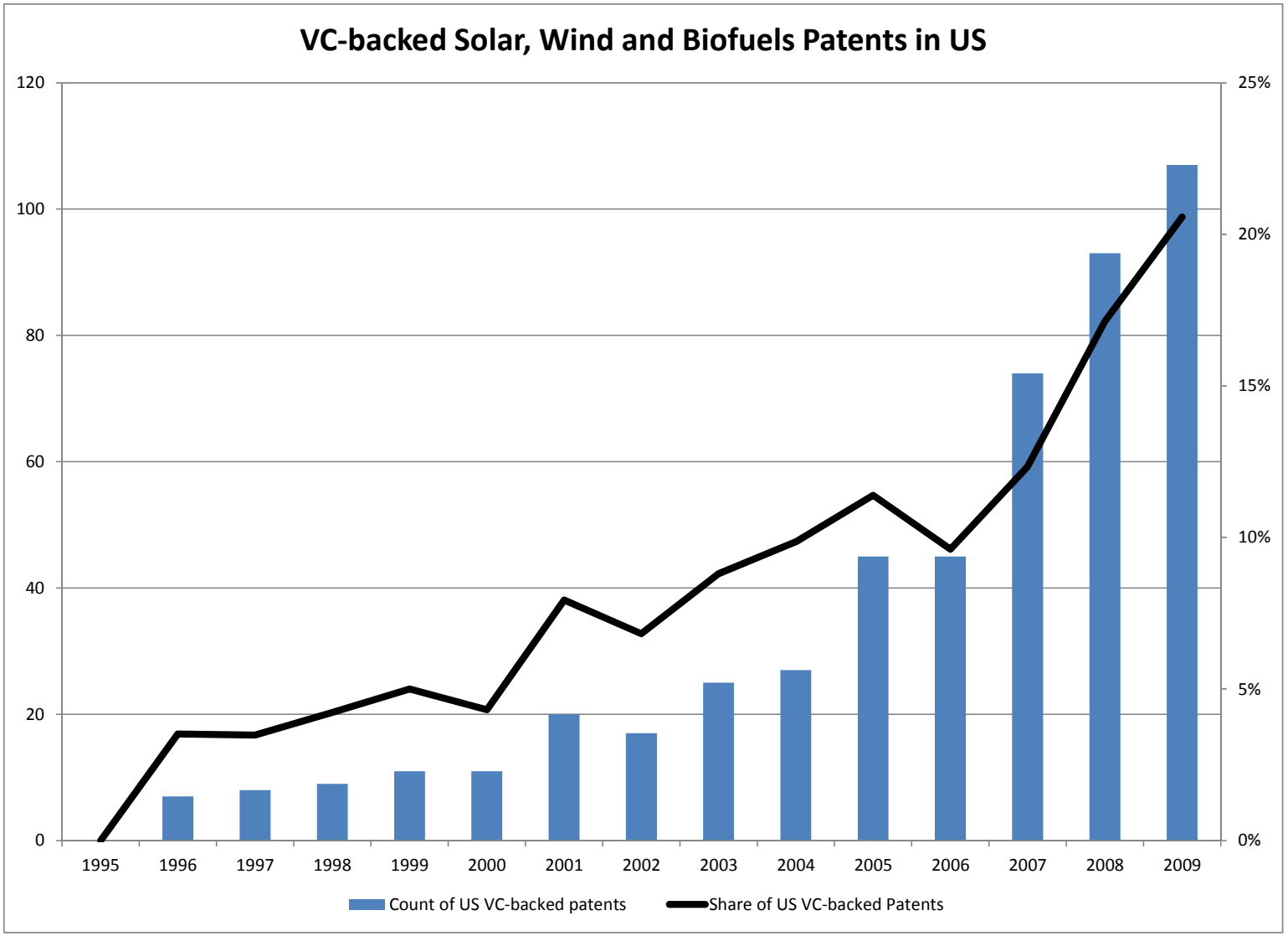
- Machine learning algorithm expands sample to 18,642
  - Still a relatively small number of patents
  - Investigating patents filed outside US

Patent Counts by Year



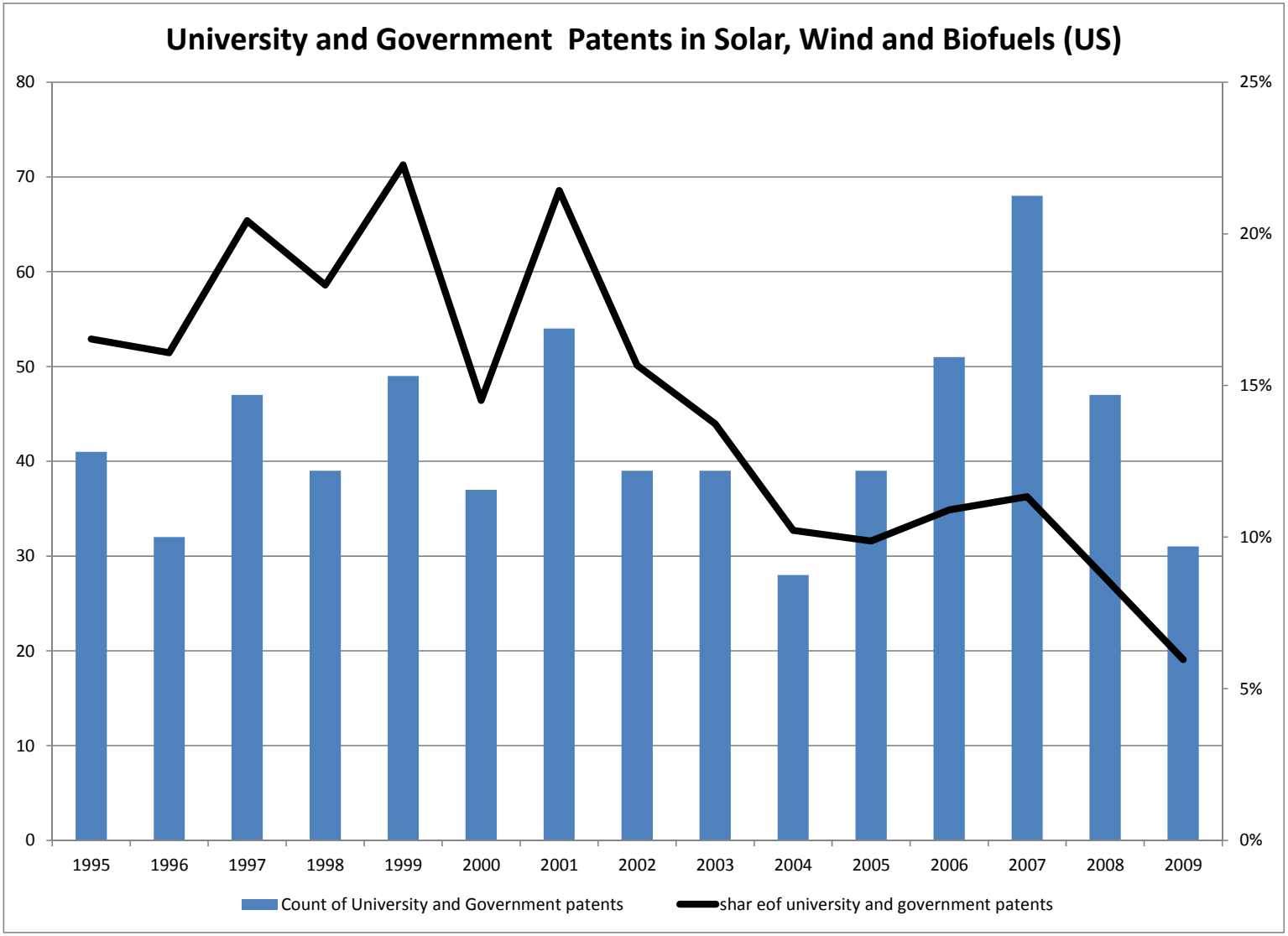
Source: IP checkups, USPTO data

VC backed patenting



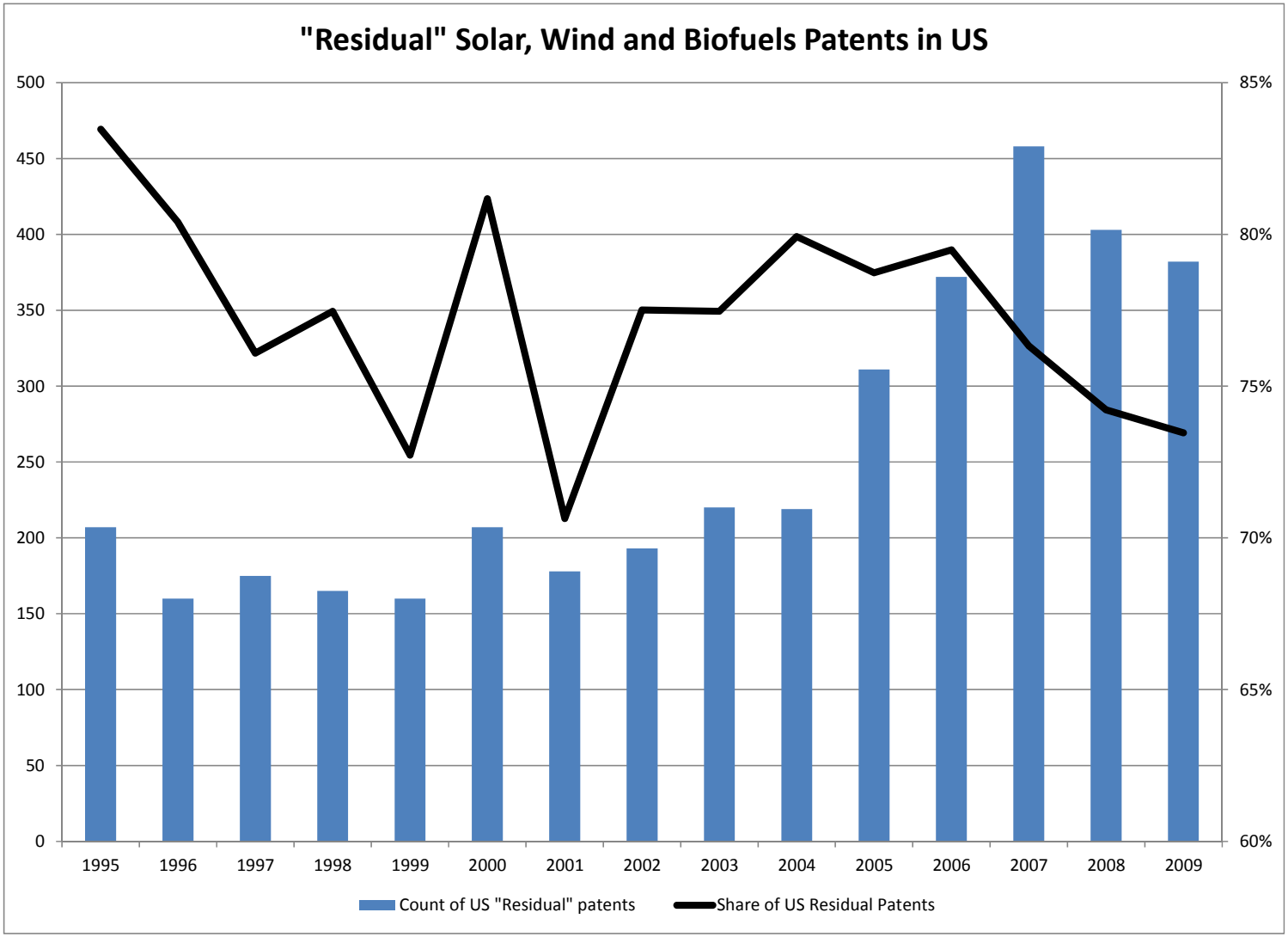
Source: IP checkups, USPTO data

University & Government Patenting



Source: IP checkups, USPTO data

“Residual Category” Patenting



Source: IP checkups, USPTO data

Patenting Trends

- US share of patenting risen from 2005-2009
  - Driven by VC-backed patenting and “residual firms”
- Rise in VC-backed patenting is particularly stark
  - In the US, increased share from 5% in 2000 to over 20% in 2009
  - Rising share outside US as well
- Decline in the share of university and government patenting
  - Movement of technologies from research to commercialization?

Potential Refinements

- Expanding scope of the analysis
  - More Clean Tech categories (include Nuclear, production vs. storage)
  - USPTO vs. other patent offices (IP Checkups has access to European and Japanese patent offices)
  - Expanding IP checkups sample based on machine-learning algorithm
- More detail within the US
  - Novelty and impact of inventions across assignee types
- “Residual Category”

VC financing samples

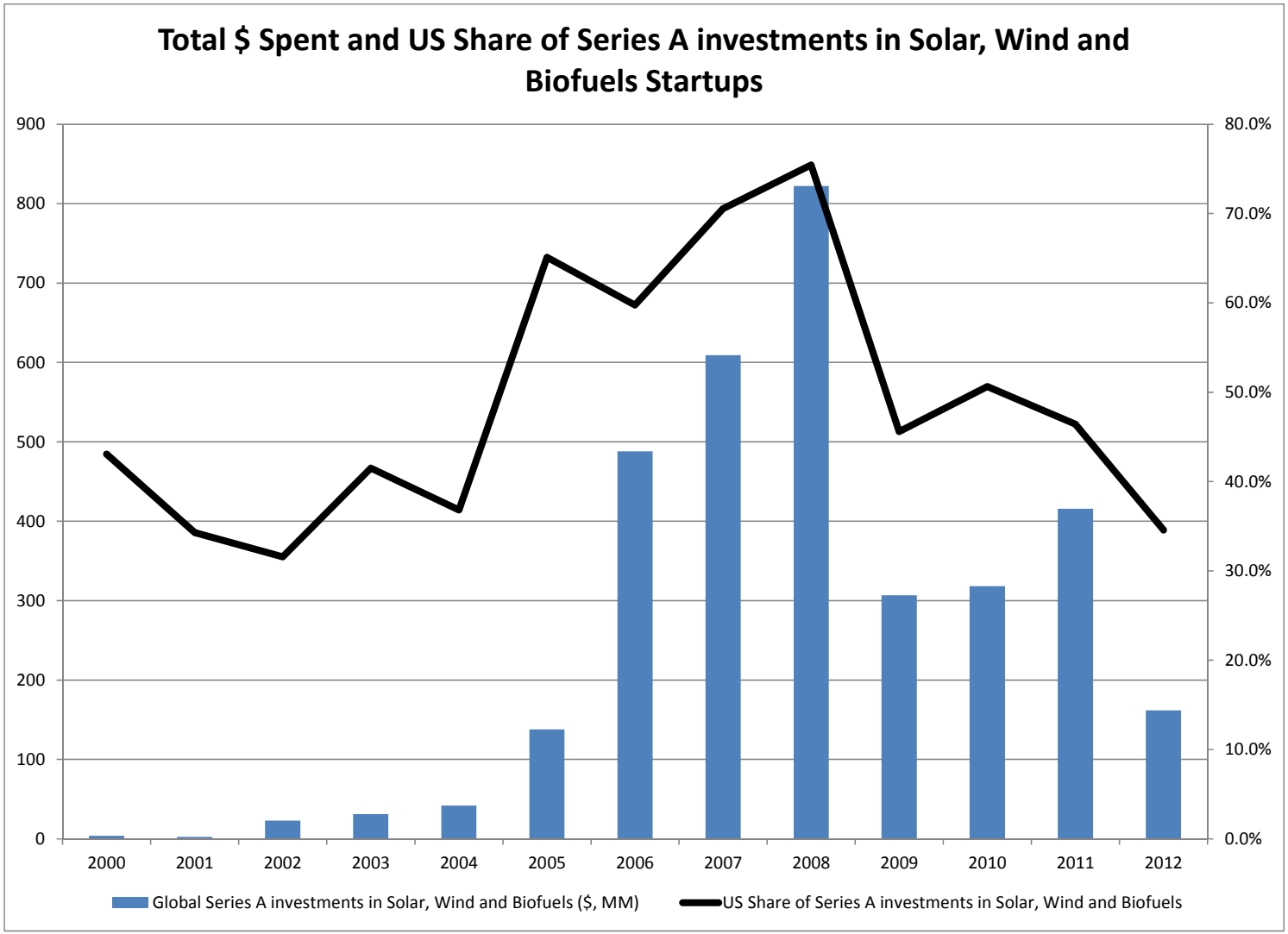
	Cleantech i3		Bloomberg New Energy Finance	
	No. of First Financings	$ MM invested in First Financings	No. of First Financings	$ MM invested in First Financings
Solar	367	1,920	343	1,636
Wind	125	515	97	418
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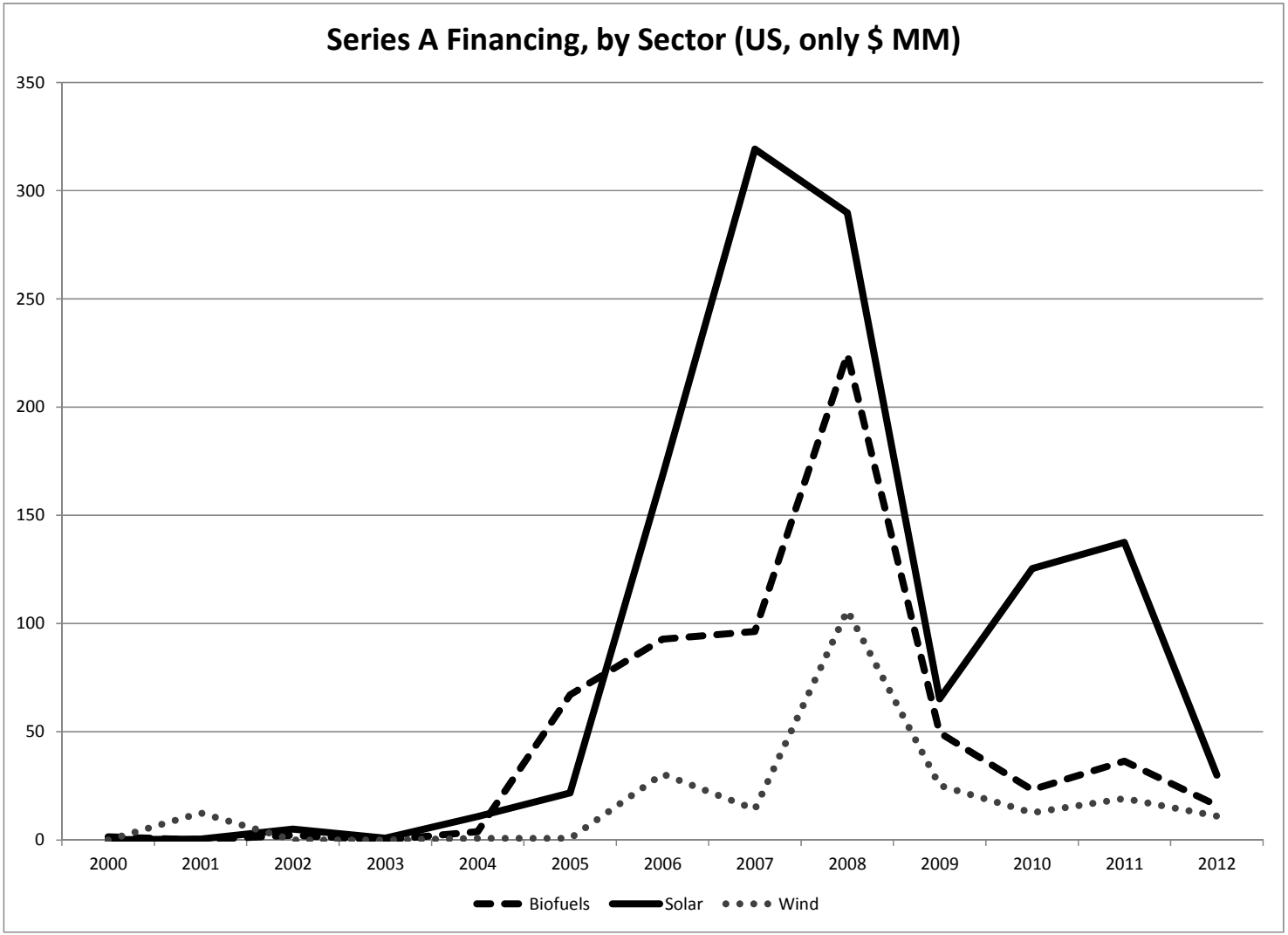
- Very consistent across totals and over time
  - Cleantech i3 somewhat more comprehensive in later years (biofuels sample slightly different due to definition)

VC dollars invested



Source: Cleantech i3

VC dollars invested



Source: Cleantech i3

VC Financing Trends

- Massive spike in financing from 2005-2009
  - Consistent with timing of spike in VC-backed patenting
- Huge drop off in recent years
  - Focus on energy efficiency / software as opposed to energy production technologies
  - Consistent with anecdotal information and aggregate data on venture capital financing
- Expect that VC-backed innovation will also drop off as the financing for these startups dries out

VC Business Model

- Highly uncertain investments
  - 60% of venture capital investments are terminated below cost
  - All money is made from few big successes
  - Hard to know ex ante which ones these will be (Bessemer Ventures Anti-Portfolio)
- Efficient Experimentation
  - Diversify across multiple investments
  - Spend as little money on early experiments to learn about prospects of the venture (“fail fast and cheap”)
  - Reinvest in winners so that own sufficient share of the few successes to make up for losses on vast majority of firms

Ideal VC investments

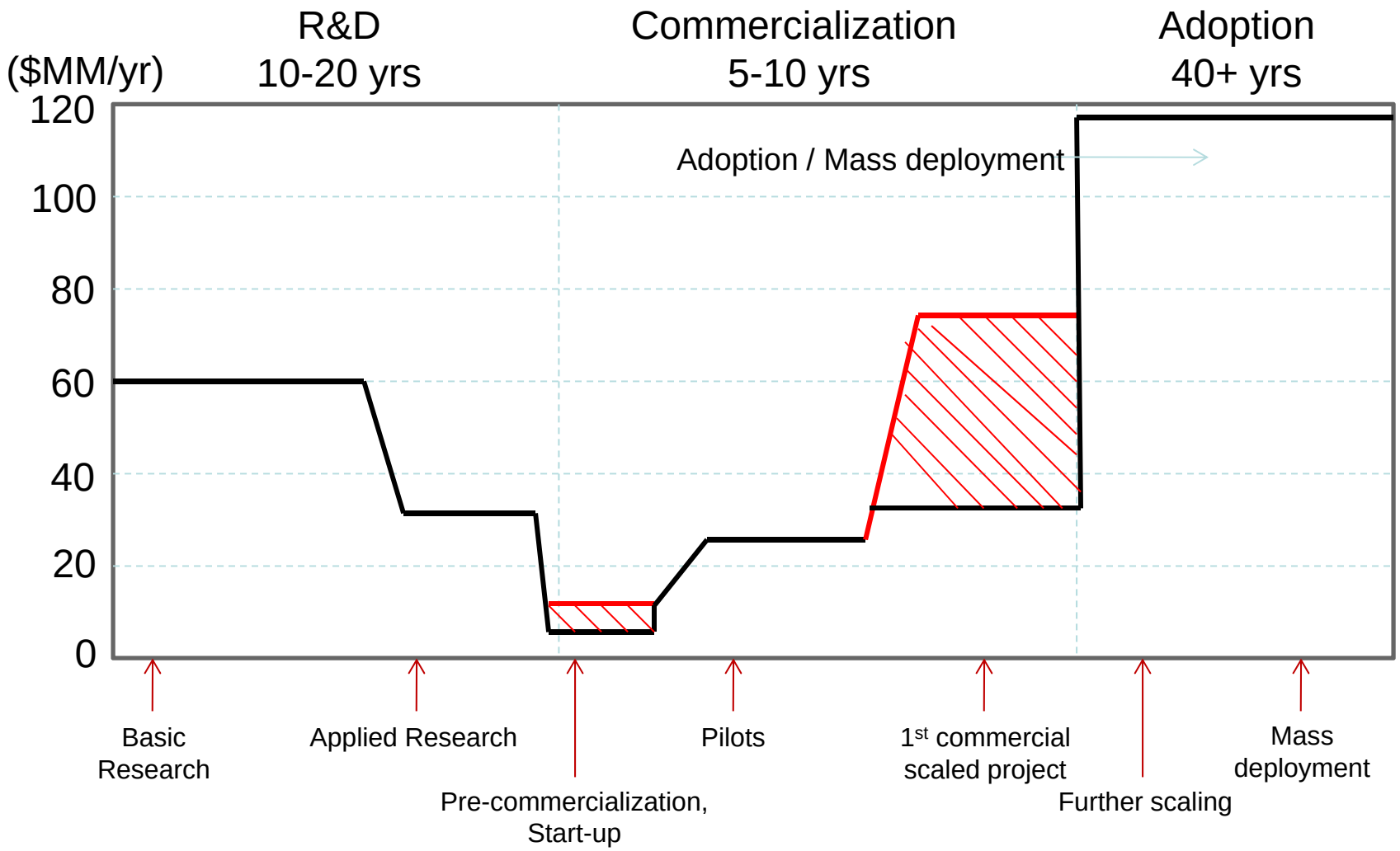
- Capital (equity) light businesses
  - Greater diversification for given fund size
  - Require less capital to learn about prospects
  - Require less capital to scale (so VC less diluted by follow on investors)

- Exit opportunities within life of fund
  - Uncertainties about viability resolved in 3-5 years
  - Buyers willing to price in growth options / network effects / scale economies
  - Often dependent on IPO markets

Clean Energy Startups

- Long development cycles
  - Need to build factories (even nuclear power plants)!
- Experimentation is costly
  - Economics only work at large scale, but hard to predict economics at smaller scale.. Need to build the factory to find out!
- End product is a commodity
  - Upside may be more limited (different from biotech)
- No well-established exit mechanism (yet)

Timelines and Costs in Clean Energy



Policy Implications

- What are the most effective policies in driving energy innovation?
  - What role of cap and trade / carbon taxes?
  - “Demand-based “ subsidies (RPS / feed-in-tariffs) vs. “Supply side” subsidies (to individual firms/ technologies) to plug the “valleys of death”?
  - Relative emphasis on R&D / commercial demonstration / widespread deployment?

- How should the private sector engage government?
  - Government Research labs?
  - Startups / venture capital
  - Role of established firms and utilities