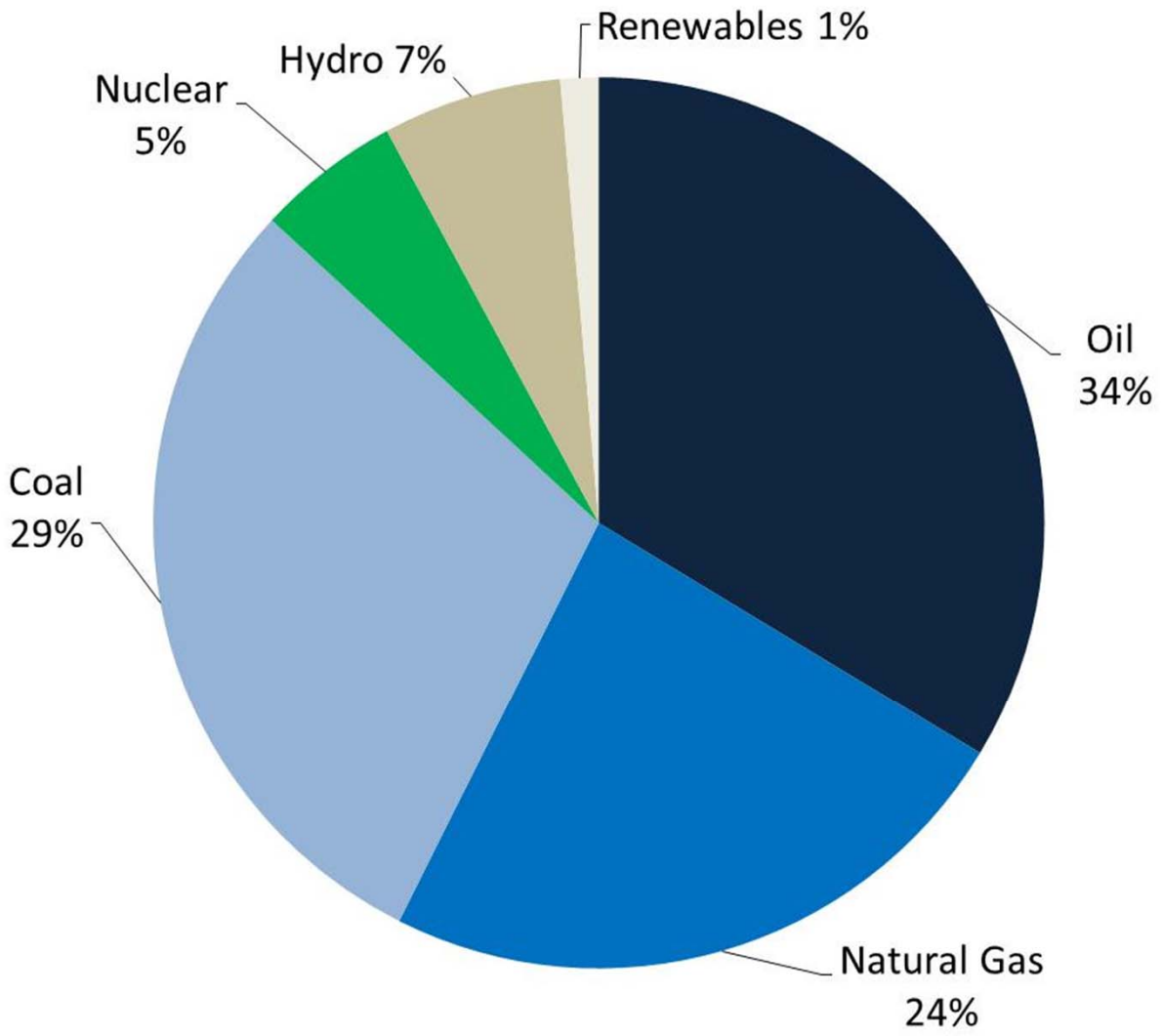
Innovation and Entrepreneurship in Clean Energy

Ramana Nanda, Ken Younge and Lee Fleming

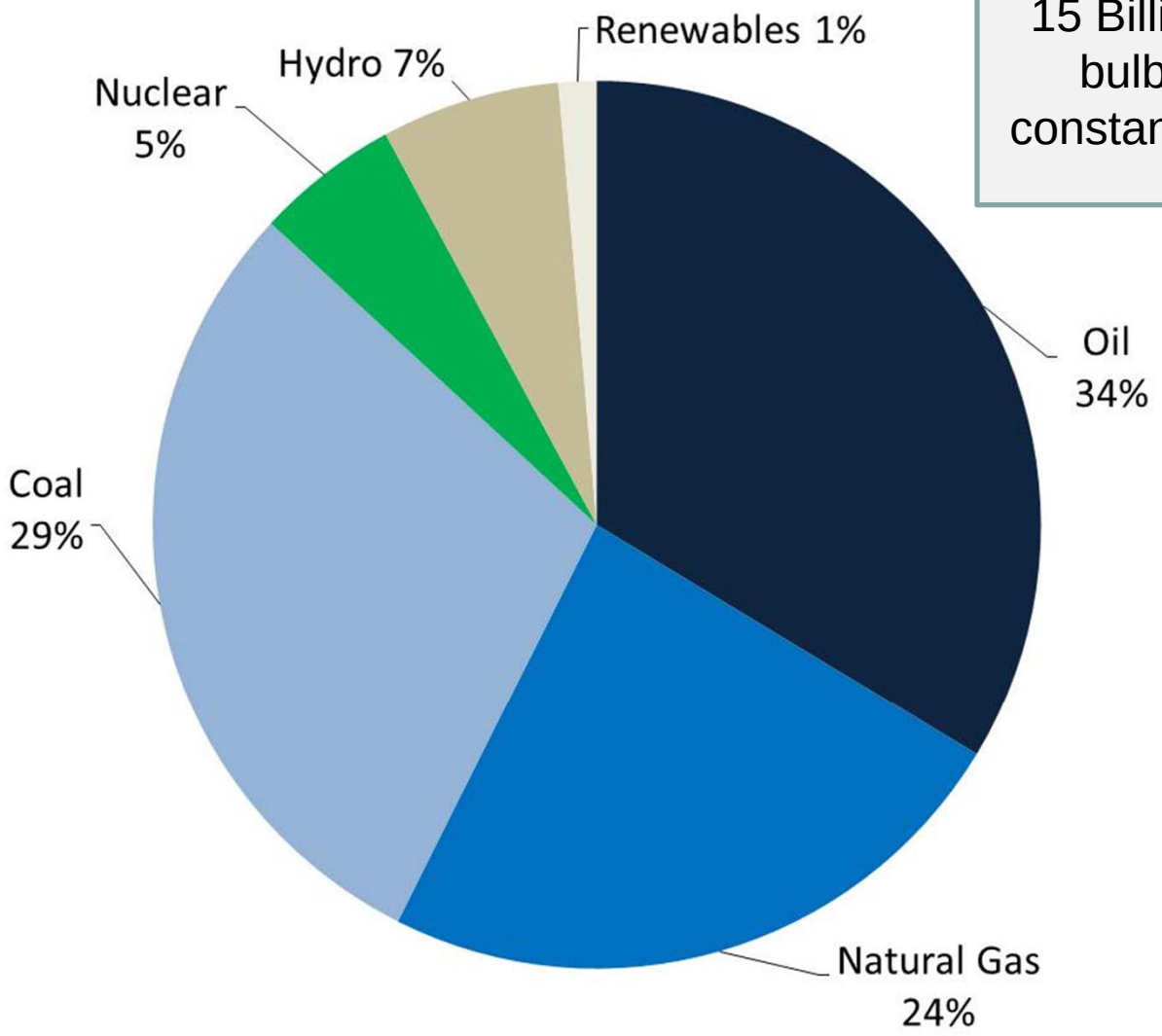
The Changing Frontier: Rethinking Science and Innovation Policy Pre-Conference

October 27, 2012

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



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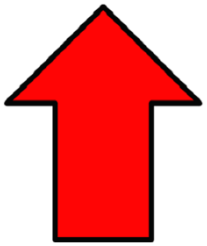
15 Billion 100 watt bulbs running constantly for 1 year

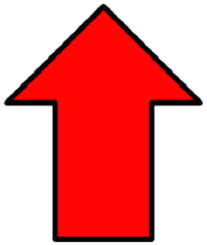
What drives the demand for energy?

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 / government?
  - In the US and internationally?
- Is the nature of innovation in these different institutional regimes qualitatively different?
  - Which technology classes?
  - Radically new vs. incremental improvements?

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 might impact trajectory of innovation
  - Academia / Government vs. Private Sector
  - VC backed startups vs. Incumbents
  - Boom and bust cycle in Venture Capital

Data Sources

- IP Checkups (1995-2009)
  - Focused on USPTO data
  - 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 details on the technology underlying the startup being commercialized

Patent Sample Breakdown

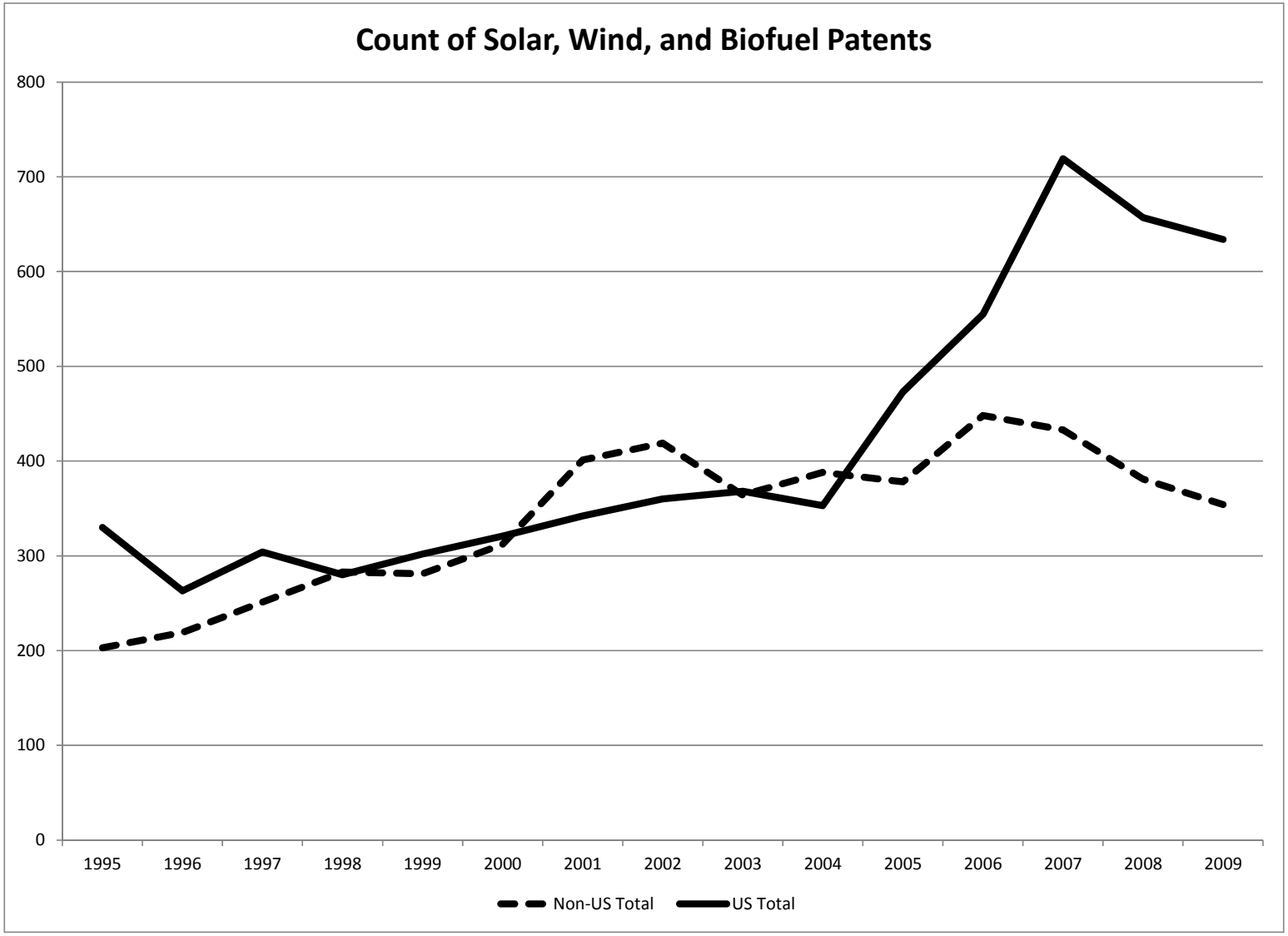
	VC-backed	University & Government	Residual with Assignees	No assignees	Total
Solar	399	368	3,219	929	4,915
Wind	258	42	1,255	668	2,223
Biofuels	141	523	3,160	414	4,238
Total	798	933	7,634	2,011	11,376

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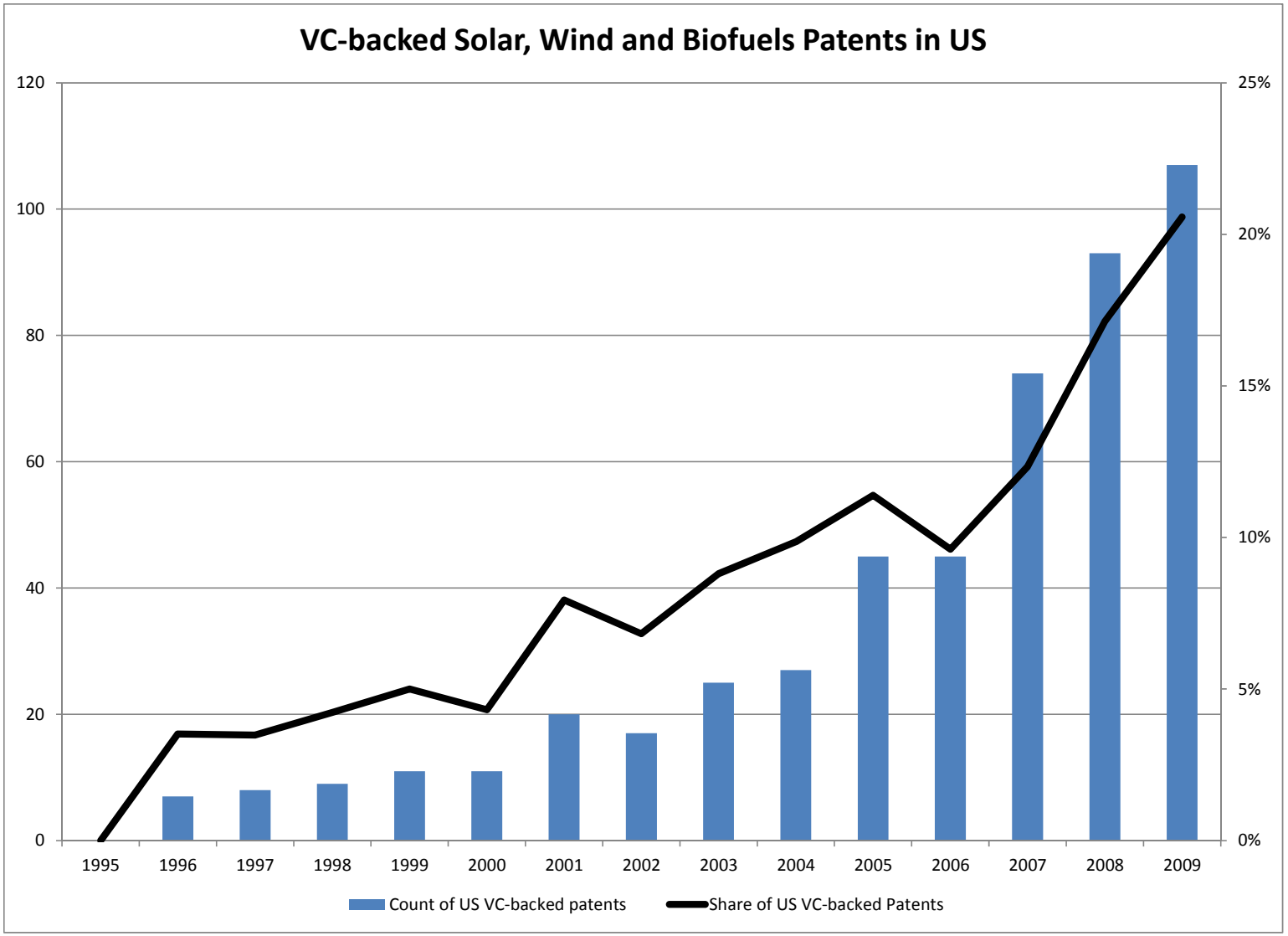
- Machine learning algorithm expands sample to 18,642
  - Still a relatively small number of patents

Patent Counts by Year



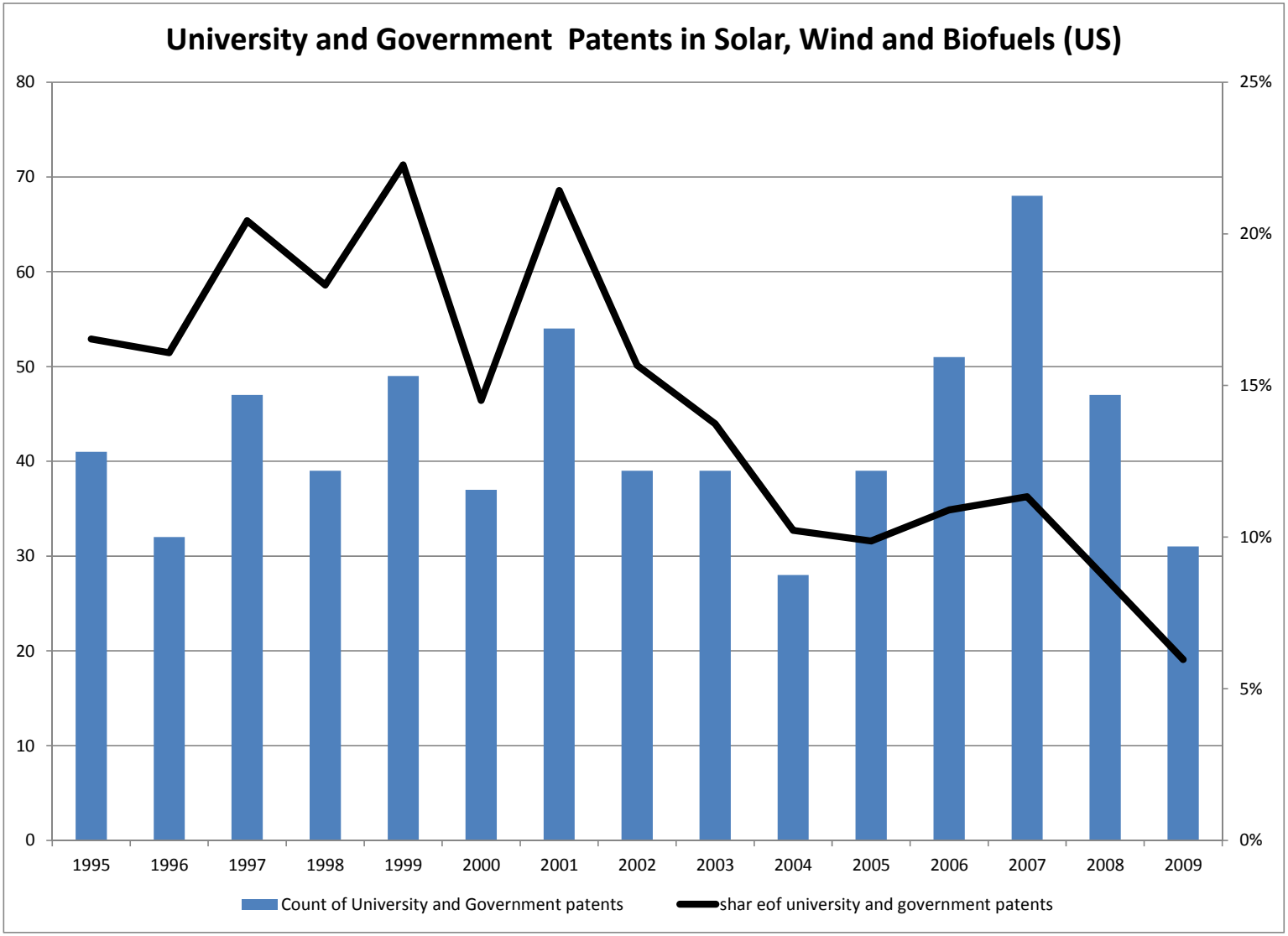
Source: IP checkups, USPTO data

VC backed patenting



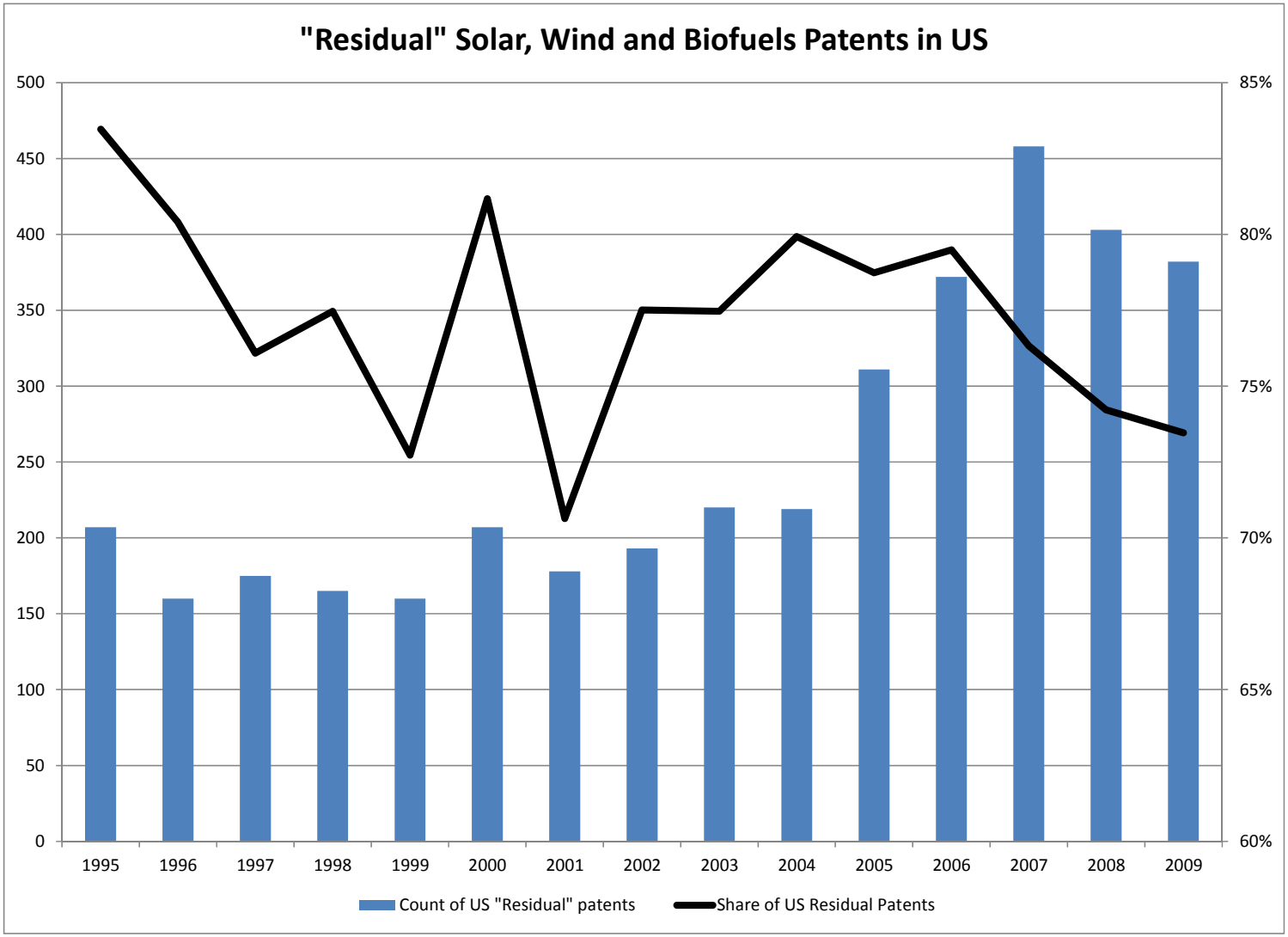
Source: IP checkups, USPTO data

University & Government Patenting



Source: IP checkups, USPTO data

“Residual Category” Patenting



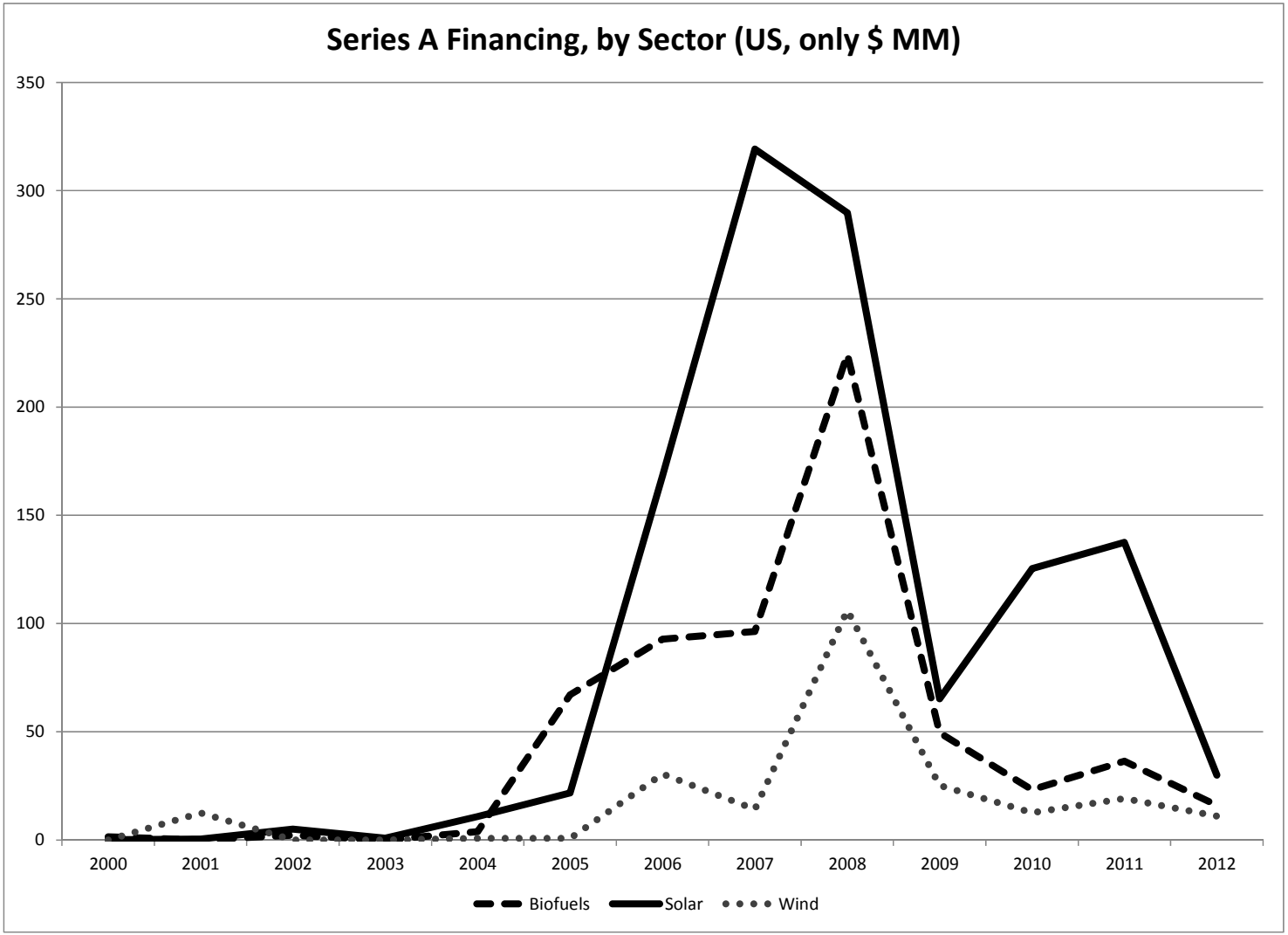
Source: IP checkups, USPTO data

Patenting Trends

- US share of patenting risen from 2005-2009
  - Driven by VC-backed patenting and “residual firms”

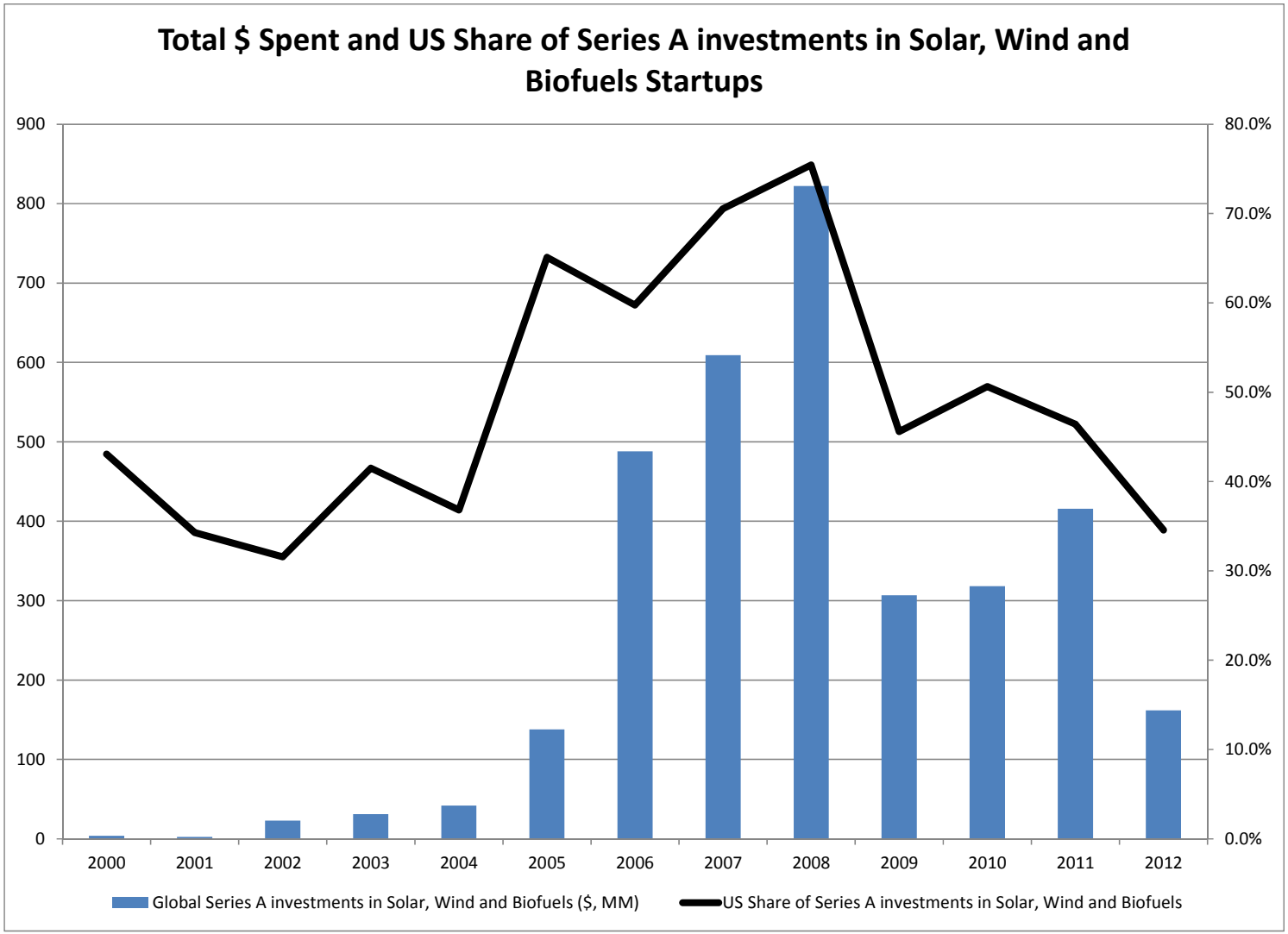
- Rise in VC-backed patenting is particularly stark
  - In the US, increased share from 5% in 2000 to over 20% in 2009
  - Rising share outside US as well

VC dollars invested



Source: Cleantech i3

VC dollars invested



Source: Cleantech i3

Was innovation by VC-backed startups qualitatively different?

- How novel and impactful?
- How related or separated in technology space from other categories?
- Across the boom and bust cycle?

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

Clean Energy Startups

- Long development cycles
  - Need to build factories
- 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)

Working on

- Expanding scope of the analysis
  - Include Nuclear
  - Expanding IP checkups sample based on machine-learning algorithm
- Qualitative understanding of innovations
  - How recently the technology subclass first seen
  - How frequently combination of subclasses seen before
  - Age of patents being cited
- Unpack “Residual Category”
  - Non-VC backed startups (Family offices, government grants)