

# ARPA-E: Versatile Catalyst for U.S. Energy Innovation

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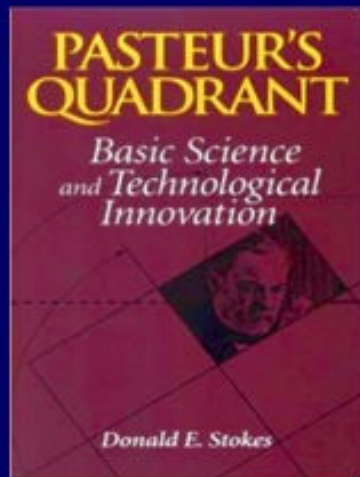


# U.S. Energy Innovation: Market Failures and Policy Weaknesses

- Market failures:
  - Underinvestment in R&D, esp. non-incremental
  - Externalities, like air pollution and climate change
  - Complex, interdependent systems
- Policy weaknesses:
  - Over-reliance on peer review allocation of R&D
  - Gaps between publicly-supported R&D and application in the energy system

High  
Relevance  
for  
Immediate  
Application

Low

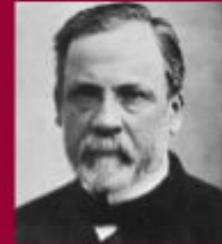


*Applied  
Research*



Edison Quadrant

*Use-Inspired  
Research*



Pasteur Quadrant

*Pure  
Basic Research*



Bohr Quadrant

Low

High

Emphasis on  
Fundamental Understanding

# ARPA-E: A Brief Introduction

- Authorized 2007, operational 2009
- Funding ca. \$300 million per year
- Hires program directors (PDs) from outside government for limited period
- Empowers PDs to fund high-risk, high-payoff projects in unexplored “white spaces”
- Actively manages project portfolio

**Figure 1: Questions That Must Be Answered for New ARPA-E Programs<sup>34</sup>**

<p><b>Program Technical Goals</b></p>	<ul style="list-style-type: none"> <li>▶ What is the global landscape of the field—science, technology, markets, players?</li> <li>▶ If successful, what specifically will the program accomplish technically?</li> <li>▶ Has the program been coordinated with DOE?</li> </ul>
<p><b>Mission Impact</b></p>	<ul style="list-style-type: none"> <li>▶ What impact would this success have on the agency mission when the technology becomes widely used—what’s new and why is it a potential game-changer?</li> <li>▶ How much better will the new technology be than existing technologies along quantitative metrics?</li> </ul>
<p><b>Technical Approach</b></p>	<ul style="list-style-type: none"> <li>▶ What are the key technical challenges and what are the ideas for overcoming these barriers?</li> </ul>
<p><b>Transition</b></p>	<ul style="list-style-type: none"> <li>▶ What is the transition strategy (risk profile and time horizon)?</li> <li>▶ What are the non-technical barriers to transition (policy, markets)? Will technology scale in cost and volume?</li> <li>▶ Who are the customers who will absorb this technology and who will potential players be?</li> </ul>
<p><b>Program Metrics</b></p>	<ul style="list-style-type: none"> <li>▶ What are the metrics, milestones, and schedule for this program?</li> <li>▶ How much will the program cost and why?</li> </ul>

# Assessing ARPA-E's performance

**Long Term Goal:** produce technologies that strengthen energy independence, reduce emissions, improve energy efficiency, and support U.S. leadership in energy technology.

**Focused Short Term Expectations:** ARPA-E is an applied research program built in DARPA's image that helps to fill gaps in the energy innovation system and complements the work of other organizations.

## **A few questions for which answers are required to assess ARPA-E:**

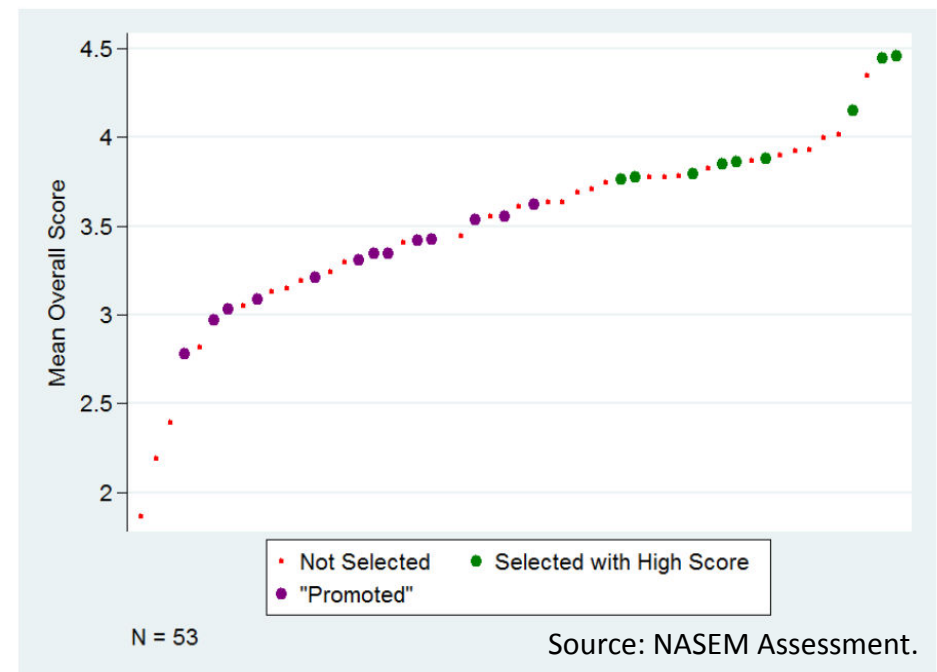
- Has ARPA-E functionally internalized DARPA's active management practices to pursue high-risk, high-reward projects? (See Goldstein and Kearney).
- How does ARPA-E's portfolio compare to other DOE grant-making agencies on innovation outputs? (See Goldstein and Nanayanamurti)
- How do ARPA-E portfolio companies compare to non-ARPA-E companies?

**This is our focus.**

# Active Program Management at ARPA-E

- Grant significant discretion to Program Directors for program design, project selection and on-going management.
- Results in pool of higher risk projects.
- PDs manage projects closely and will cut projects short if necessary to mitigate downside risk.

Figure 10: PD Discretion in Selection (RANGE Program)

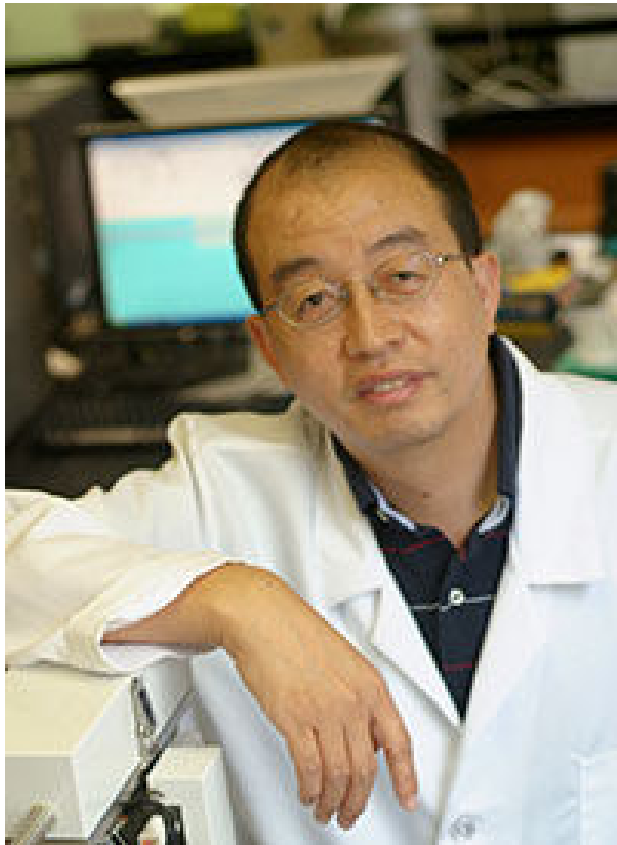


# ARPA-E Compared to OS & EERE

- ARPA-E projects are equally likely to yield academic publications as similar projects funded DOE's Office of Science (OS).
  - Surprising result given that incentives for publication are weaker for ARPA-E recipients.
- ARPA-E projects were more likely to produce a patent than similar projects within EERE.
  - Also more likely to be cited by later patents.
- ARPA-E projects were at least five times more likely to produce both a patent *and* a publication as comparable OS or EERE projects.
  - Evidence that ARPA-E is able to expand the boundaries of scientific fields while simultaneously serving as a conduit for impactful applied research.



# ARPA-E AWARDEE HONG-CAI ZHOU



Robert A. Welch chair,  
Chemistry Department,  
Texas A&M University

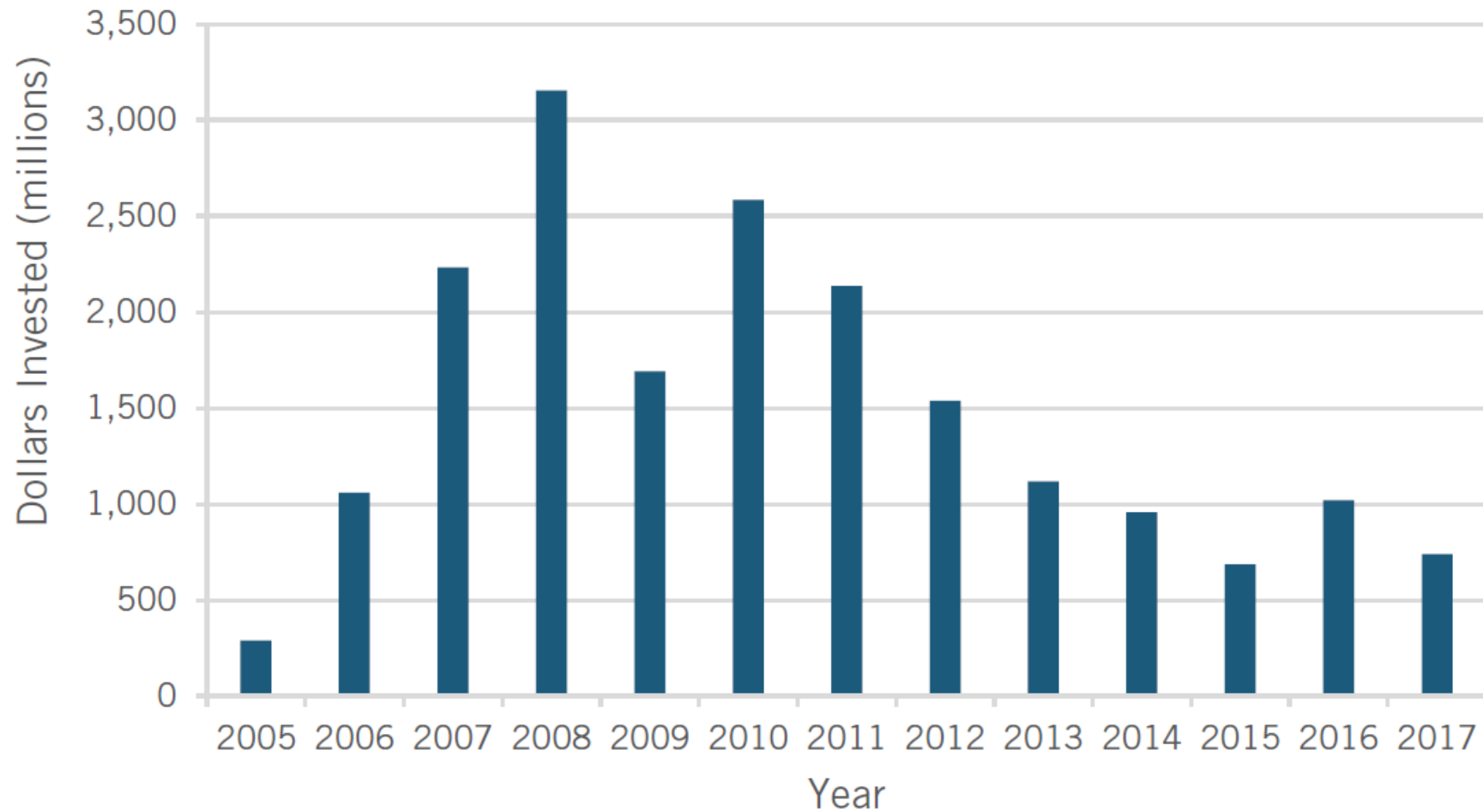
- Awards in 2010 and 2012
- Metal-organic frameworks for carbon capture and natural gas storage
- ARPA-E awards cited in 53 papers with almost 4000 citations
- Start-up firm framergy licensed IP, raised \$1.85M

# ARPA-E Commercialization Metrics

- 56 new companies formed
- \$1.8 billion in private-sector follow-on funding.
- 14 commercial products
  
- But, these numbers need to be considered within the context of broader financial trends in cleantech.
  - We assembled an exhaustive dataset of funding announcements for “cleantech” firms from 2000-present.

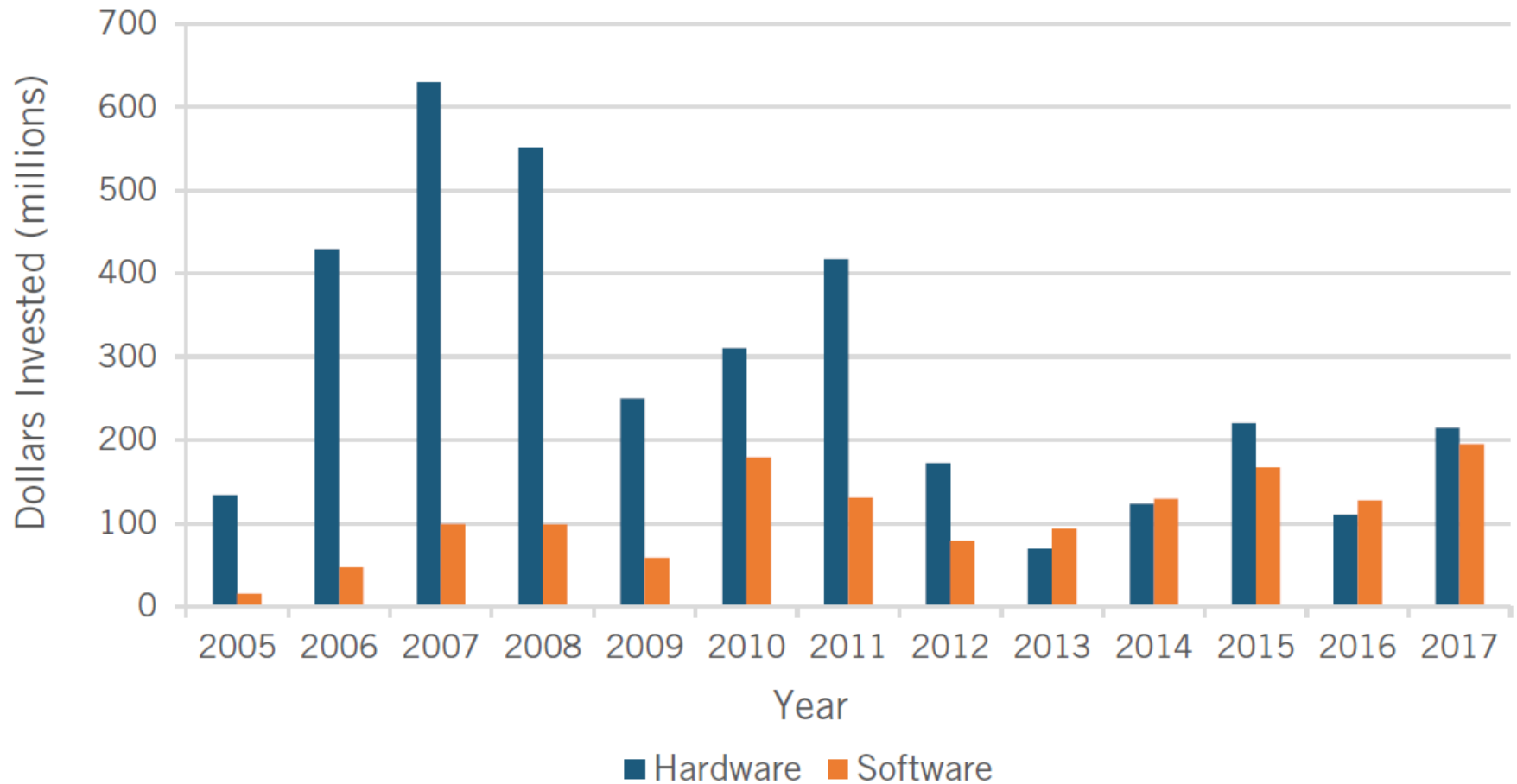
# Trends in Cleantech Financing

Figure 4: Dollars invested in private equity cleantech deals, 2005-2017



# Trends in Early Stage Cleantech Financing

Figure 10: Dollars invested in hardware and software private equity cleantech deals, 2005-2017



# ARPA-E Firms Fare Well in This Environment

Table 1: Regression Analysis of ARPA-E Funding Impact on Follow-On Funding

	(1) Follow-on Funding	(2) Top 50th Percentile	(3) Top 10th Percentile	(4) Gov. Funding
ARPA-E	0.521* (0.293)	0.731* (0.404)	1.698*** (0.509)	1.031** (0.411)
Hardware	-0.084 (0.249)	-0.112 (0.360)	0.772 (0.892)	0.019 (0.518)
Year Founded	-0.211*** (0.033)	-0.213*** (0.056)	-0.474*** (0.104)	-0.086 (0.069)
Tech Sector Fixed Effects	YES	YES	YES	YES
Model	OLS	Logit	Logit	Logit
Observations	320	318	286	314
R2	0.203			

Standard errors in parentheses

Prequin Data Full Sample

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

# Recommendations

1. Maintain ARPA-E's operational autonomy and distinctive operating procedures.
2. Expand ARPA-E's budget.
3. Reauthorize ARPA-E.
4. Establish an ARPA-E trust fund to stabilize its budget.
5. Infuse ARPA-E practices into the rest of DOE.



# Thank you!

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