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

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• 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
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

<table>
<thead>
<tr>
<th>Program Technical Goals</th>
<th>What is the global landscape of the field—science, technology, markets, players?</th>
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<tbody>
<tr>
<td></td>
<td>If successful, what specifically will the program accomplish technically?</td>
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<td>Has the program been coordinated with DOE?</td>
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<td>Mission Impact</td>
<td>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?</td>
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<td>How much better will the new technology be than existing technologies along quantitative metrics?</td>
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<td>Technical Approach</td>
<td>What are the key technical challenges and what are the ideas for overcoming these barriers?</td>
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<td>Transition</td>
<td>What is the transition strategy (risk profile and time horizon)?</td>
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<td>What are the non-technical barriers to transition (policy, markets)? Will technology scale in cost and volume?</td>
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<td></td>
<td>Who are the customers who will absorb this technology and who will potential players be?</td>
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<td>Program Metrics</td>
<td>What are the metrics, milestones, and schedule for this program?</td>
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<td></td>
<td>How much will the program cost and why?</td>
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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.

Source: NASEM Assessment.
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.

Source: NAS Assessment, Goldstein and Nanayanamurti.
ARPA-E AWARDEE HONG-CAI ZHOU

- 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

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

Source: NAS Assessment
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

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

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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