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Energy: A defining challenge for the 21\textsuperscript{st} century

The world must provide more and more energy to fuel growing global economies, while:

- \textit{Environmental impact}: Significantly reducing pollution, especially carbon emissions that pose a risk of catastrophic climate disruption
- \textit{Economic impact}: Reducing dependence on fossil fuels concentrated in some of the world’s most unstable regions, expanding share of global clean-energy markets
- \textit{Security impact}: Reducing risk of resource conflicts, nuclear proliferation, military dependence on imported fuels
- \textit{Poverty impact}: Providing access to improve the lives of billions of people who lack access to modern energy supplies

\textit{These challenges cannot be met at reasonable cost without new and improved energy technologies}

\textit{The U.S. and other governments have long played a role supporting technology development in energy}
Types of technologies that can be important in the future of the electricity sector

- Technological improvements to enable grid modernization include:
  - improving grid observation, understanding, and operation
  - improving control of energy and power flow
  - developing and deploying energy storage

- Technologies to provide clean (or cleaner) electricity
  - Solar power, wind, geothermal, fuel cells, IGCC, carbon capture and storage, new nuclear designs, and others
  ➔ need to be compared across many metrics in addition to cost: greenhouse gas emissions, modularity and scalability, water consumption, infrastructure compatibility
Basis and criteria used by U.S. government to make decisions on technology choices

Traditionally U.S. government support has been organized around individual program lines (e.g., solar, bioenergy, industry efficiency, transmission and distribution) and based on annual budgets.
Large volatility in U.S. policy deters innovation

Every year there is a 1/3 chance that budget will change by 27%
Experts estimates of impact of increased RD&D on technology improvement

- Median impact largest for solar PV, batteries, and bioenergy
- Median impact smallest for vehicles technologies and fossil energy
Decisions about allocation of investments should account for technical uncertainty.

Even if all the optimistic experts are right, and technologies do as well as they possibly can, and the government makes very large RD&D investments, a demand-side policy is needed.
New modeling tools can contribute to a better understanding of portfolios accounting for uncertainty

Under other a CES policy solar PV RD&D would play a larger role in the portfolio, and under a no policy case biofuel RD&D would play a larger role.
Technology choices and risks

- If the government has a role supporting ‘beneficial’ technologies, then choosing at some level is inevitable.
- The level of risk (and the loss given failure) increases as we move closer toward commercialization.
  - If there were no failures, government would be crowding out private funds.

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<tr>
<th>Phase</th>
<th>Range</th>
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<tr>
<td>R&amp;D</td>
<td>$100k-$1m</td>
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<tr>
<td>Demonstration Or Debugging</td>
<td>$10m-$100m</td>
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<tr>
<td>Niche Markets</td>
<td>$100m-$1b</td>
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<tr>
<td>Diffusion</td>
<td>$10b-$100b</td>
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Dolezalek (2010)
Wide range of publicly-supported energy innovation institutions

- ‘Old institutions’ in blue, newer institutions in red, and non-existing institution in purple

- Different institutional models allow different types of innovation, although more time is needed to evaluate effectiveness
Designing energy R&D subsidies

- R&D allocation should be complemented with analysis considering the uncertainty around future outcomes and the interaction of technologies in the marketplace.

- Current energy R&D subsidies are not learning from experience:
  - Very limited information collected on effectiveness and crowding out of private investment in grants and cooperative agreements
    - ARPA-E seems to be addressing this problem with active management strategies
  - Very limited information collected on the outcome of partnerships or agreements with other countries.

- National labs need to:
  - Increase interaction between users (private sector), scientists at the labs, and DOE program managers.
  - Restructure contracting to allow for increased lab autonomy but strengthen accountability through periodic robust internal and external review to ensure a merit-oriented culture.
  - Put in place more incentives for entrepreneurship.
Policy principles for technology demonstrations

1. Long-term policy
   – Lack of sustained policy objectives, vision and strategy as the single biggest barrier to private sector investment

2. Commercial viability and credibility
   – Ready for demonstration?
   – Value of technologies in different oil and gas price environments

3. Materiality
   – Have a material impact on one or more of the three objectives

4. Information dissemination
   – Balance between protecting IP and public information sharing

5. Exit strategy
   – Continued support conditional on performance
   – Active management strategies
   – Taper off incentives rather than binary on-off (e.g., production tax credit)

Anadon et al. (2010)
Policy principles for technology demonstrations (II)

6. Public-private partnership

7. Cost sharing
   – Sharing of costs and risks
   – 50% rule - “too rigid” or indication that “project is worth pursuing”

8. Targets and objectives
   – Targets drive investment and definition of success
   – Clear criteria for technical performance and avoid targets vulnerable to external factors

9. Portfolio approach
   – Promote range of competing technologies
   – Portfolio can’t include everything due to fiscal constraints
   – Accommodate project failures

10. International partnerships
Concluding remarks

- There are many reasons for government support for the development and demonstration of technologies in the electricity sector.

- Current decisions on energy R&D investments do not properly account for the interaction of technologies in the marketplace and policy and technical uncertainty.

- Additional areas for improvement include:
  - Increased monitoring and evaluation of current activities, utilizing active management strategies and having ‘learning’ as a central focus.
  - Treatment of the system of institutions and investments as a portfolio.
  - Providing support for demonstrations following a set of principles.
  - Internalizing the possibility that a technology that is supported may not be commercialized in the design of programs.
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