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Will the search for new energy technologies require a new R&D mission agency? – The ARPA-E debate

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The Energy Technology Challenge

Energy is a high-stakes problem for the US, with much hanging in the balance - energy security and resource dependency on the Middle East, climate change, economy-wide shakedowns from high cartel-imposed prices, disruptive trade imbalances, and macroeconomic trade costs. In response, some have advocated a Manhattan Project for new energy technology, or the equivalent of the Apollo Moon Program. But those famous projects were focused on single technologies to be set up in comparatively short-term multiyear projects, and were simple compared to the present energy technology challenge. The earlier technologies were launched for a single customer with the deepest pockets - the government sector - not for deeply

imbedded, stratified, and highly competitive private sector markets. The energy challenge requires a very different development model in which a complex mixture of energy technologies must evolve over decades in the private sector. As some have noted, there will be no silver bullet for a short-term energy fix.

An array of new energy technologies is needed. Some technologies have been tested at economic scale and are ready for demonstration and implementation, others require breakthrough research, still others need both breakthroughs and large-scale development. These technologies demonstrate that a new energy economy is possible in the US if we have the political will to make it happen. A key point is the need for many strands of technology development in multiple timeframes; there cannot be a single technology focus. And the new technology development system will need to maintain room for continuing advances over time - there will be 2nd generation batteries and solar panels, and then 3rd and 4th generation advances will displace their predecessors. So there must be opportunities to promote both incremental advances and disruptive new technologies: technological arterial sclerosis should be avoided. With a complex systems problem, multiple energy technology pathways must evolve over time. Each path will be different, although many will have to be complementary. This may be the most complex technology evolution problem the US has ever faced. Reaching the moon starts to look simple by comparison.

The current policy prescription for climate change contemplates a demand-side approach, where a macro price for CO_2 is imposed across economic sectors, probably through a cap-and-trade system. However, price by itself will not yield advances in alternative energy technology. Technology demand encourages, but does not create, new technology - an innovation system is also required. Arguably, the innovation supply-side, including new innovation institutional arrangements, will also need attention, with technology supply efforts working in tandem with pricing signals from a demand-side program.

The Translational Model for Energy Technology Innovation

Will ARPA-E overcome the "Valley of Death" between research and technology?

Over the past half century, the most difficult step in a technological revolution has been to bridge the "Valley of Death" between research and innovation. The government has played a major role on the innovation "front end" by supporting R&D, and on the "back end" by supporting technology prototyping and initial market creation, largely though the defense technology sector.

The most successful model for bridging the gap between research and innovation - moving from the front end to the back end - in the US innovation system has been the Defense Advanced Research Projects Agency (DARPA), established by President Eisenhower in 1957. While DARPA has played many roles over the years, its most important role is sometimes described as working "right-left." DARPA rejected the "basic science only" model of most US R&D agencies and aimed for a "connected" model that bridges the "Valley of Death," linking research and late stage technology development up to the prototype stage. DARPA has connected the stages in the US R&D pipeline that have traditionally been institutionally separated and has put R&D and technology on a continuum by following the "right-left" model: DARPA decides up front on a breakthrough technology that must be achieved on the right side of the innovation pipeline, then reaches back to the left side of the pipeline to find the most promising scientific breakthroughs that should be nurtured to reach that goal. This is

in contrast to the curiosity-driven research-without-regard-to-technology-objective that dominates the ethos of most US fundamental science agencies. To borrow a phrase from MIT's President Susan Hockfield: For science to achieve success, it is important to sow fields of wildflowers; sometimes it is also important to bring those wildflowers into a garden.

A good term for DARPA's role is "translational" - translating science breakthroughs into technology that gets set up and implemented. As Erich Bloch, President Reagan's noted NSF Director, once pointed out, research that collects dust on a shelf is not worth much to our society. DARPA nurtures technology to make sure it gets off the shelf.

In a 2006 report, the US National Academies of Sciences noted that DARPA-like translational "connected science" technology development is not currently carried out at the Department of Energy (DOE). To remedy this situation, they proposed that an "ARPA-E" (Advanced Research Projects Agency - Energy) fill that institutional gap.[1] DOE is home to the Office of Science, which supports primarily fundamental research and is not in the technology transition field, and the Office of Energy Efficiency and Renewable Energy (EERE), which undertakes primarily later-stage applied and demonstration projects. The DOE is also home to a network of energy laboratories historically assigned to the nation's nuclear weapons stockpile, with high overheads for a single customer (the government), and a limited history of transitioning technology into the commercial sector. While these DOE entities house some outstanding science talent, none are in the DARPA-like translational business. Given the need for breakthrough energy technologies and their transition to the commercial sector - truly the technology grand challenge of our time - Congress has been considering whether this institutional gap in energy innovation should be closed. ARPA-E authorizing legislation is now moving on both sides of Congress.[2]

While DARPA developed technologies in the defense sector, it also launched many

into the civilian economy - some of its most famous projects were in this latter category. An ARPA-E could take advantage of federal energy procurement to support emerging technologies, but launching these into the civilian economy would dominate its efforts. Although an ARPA-E cannot impose technology solutions on the private sector, it can expand the technology options and reduce the technology set-up barriers and risks for private sector firms. An ARPA-E would need to work with the private sector to identify the energy technology leverage points, what technology paths could have maximum impact, and collaboratively explore and nurture technology opportunities.

Capturing the DARPA Culture - the Hybrid Model and the DARPA Rule-set

The key to DARPA's success has been its culture of innovation, and a DARPA clone will not work unless it is able to build such a culture. An essential ingredient has been its creation of "hybrid" collaborative teams, combining the best university researchers on the research side with outstanding firms (usually start-ups, small or mid-sized firms hungry for technology advance) on the development side. This university-industry hybrid approach has proven a key mechanism for DARPA's success, particularly on revolutionary technology breakthroughs - these teams create the capability for bridging the "Valley of Death." DARPA also competes for research talent, looking for and regularly obtaining the country's most talented research teams. An ARPA-E must find new entrants and talent to supplement the existing researchers working in energy R&D, in order to have the needed breakthroughs. A competitive, hybrid model is the means to this end.

An innovation culture cannot be legislated, but Congress can put management guidance into its legislation and encourage an ARPA-E to hire those with translational research experience - a basic research background is not enough. Researchers must be recruited who have set up or worked in innovative companies and know how to bridge R&D. For a DARPA-like culture to flourish in the energy field, an ARPA-E should draw from DARPA's rule-set:

· Stay small and flexible

· Operate a flat-non-hierarchical organization packed with first-rate, cross-disciplinary technology talent

· Be freed from the bureaucratic impediments of contracting and hiring

· Create collaborative networks among research teams

· Retain a core group that knows how to work with the government bureaucracy, but rotate the bulk of the staff every four or five years to embrace change and new opportunities

· Vest leadership in outstanding program managers

· Back risk-taking in research.

It is also important for Congress to exercise strong oversight, particularly at the time of start-up. It takes two to translate - the executive along with the legislative branch must affirm this approach and do it right, to be successful.

Other Organizational Issues

The Island/Bridge Model:[3] For all innovation entities in the business of setting up new technologies, the best model historically has been to put them on a protected "island" free to experiment, and away from contending bureaucracies. However, if ARPA-E is set up within DOE, it will require isolation and protection from rival R&D agencies at DOE that may battle it for funding. Therefore, it will need a bridge to top DOE leadership to assure it a place in the R&D sun. If ARPA-E is *not* housed in DOE[4] , another option would be to create a wholly-owned government corporation entirely outside of DOE6, where it will face fewer hiring, salary, and procurement restrictions. Government corporations are most successful when they pursue limited programs with limited visibility that do not conflict with major interests or other parts of the national power structure; but ARPA-E is likely to have a much more prominent role because of the importance of energy in national politics. Highly visible programs

housed in government corporations can founder without strong connections to national leadership; if a government corporation model is selected for ARPA-E, the Secretary of Energy could be named as chairman of its board with government control of the board, to strengthen the connection to the government leadership.

Lessons from HSARPA: Congress previously attempted to authorize a DARPA clone, HSARPA, within the Department of Homeland Security's Science and Technology Directorate. While the Congress provided HSARPA with a strong and flexible authorization, closely modeled on DARPA's strengths, HSARPA has never been adequately utilized or implemented. Although a talented staff was initially recruited for HSARPA, a director was not named for approximately a year, so it lacked leadership for the start-up process in a competitive atmosphere. HSARPA was never allowed autonomy and flexibility, but was closely controlled by a budget and policy bureaucracy within the S&T Directorate that limited HSARPA's funding and essentially made all R&D investment and award decisions. It currently exists as a shell with a minimal budget. The failure to implement HSARPA as authorized illustrates several points:

· The innovation culture critical to success cannot be created by legislation alone unless the implementing agency shows real leadership, supports the new R&D mission, and is determined to use flexible statutory authorities to create a strong entity

· An ARPA-E needs its own budget and the ability to control it, rather than taking its funding from other competitor agencies that will dispute the diversion

· An ARPA-E needs technical talent of great skill with leaders who also have experience at the helm of government R&D entities, and so can work with other agency bureaucracies

· An ARPA-E needs a clear mission - breakthrough technology or incremental

technology (HSARPA tried both); mixing the two risks having the former become the billpayer for the latter.

The HSARPA implementation problems also underscore the need for ongoing Committee oversight of any implementation of an ARPA-E.

The Need to Operate at Scale

The energy sector is a trillion dollar sector, one of the largest in the US economy, and a modestly funded R&D effort will not drive transformational shifts in this sector. Federal energy R&D has fallen by more than half since a high point in 1980, and private sector energy R&D has similarly decreased. The current levels of R&D expenditure compare poorly with other major federal R&D efforts (the Manhattan Project, the Apollo Program, the Carter-Reagan Defense buildup, and NIH Doubling)[5] that were simpler and more straightforward, from an economic set-up basis, than the complex technology focus for energy. Without significantly improved investment, we will not meet our need for advances in energy technology, despite our energy security and climate challenges. We are not going to get there on the cheap.

However, R&D will not be the most expensive aspect of launching new energy technologies. Research costs are low compared to the costs of prototyping, demonstration, and initial production. An ARPA-E must nurture a wide range of technologies in a wide range of energy and efficiency fields, a task certainly comparable in complexity to DARPA's task. DARPA's $3 billion annual budget provides a rough benchmark of the range an ARPA-E should reach, after an initial phase-in period. If ARPA-E does not operate at scale, it will not be taken seriously by the best potential researchers or by talented potential employees.

If the US adopts an effective macro-pricing system for carbon (such as a cap-and-

trade program) because of climate change concerns, the program could be structured to generate revenues of up to many billions each year as a carbon-permitting system is put into place. Although this macro-pricing step is probably some years away, it will not work unless it is supported by a strong innovation system. Much of these new revenues will be needed for R&D and to leverage large scale industry transition to non-CO2-emitting energy systems. Innovation system reforms must be adopted now if these future resources are to be efficiently and soundly invested in new technologies. ARPA-E is potentially part of that innovation institution story.

Summary of Key Points

1) Starting up new energy technologies is a major and complex challenge, perhaps the most difficult technology set-up challenge the US has ever faced.

2) There is a gap in the federal innovation institutions for energy in the area of translational research. New institutional arrangements must evolve and transition to new breakthrough technologies. An ARPA-E modeled on DARPA could help fill that gap.

3) If an ARPA-E entity is formed, its success will require high performance from outstanding new research entrants, following the DARPA hybrid model of the best university and firm researchers.

4) The culture of ARPA-E will determine its success; authorizing legislation should include management guidelines following key points in the DARPA rule-set that have created an effective culture there.

5) ARPA-E could be started up either inside or outside DOE, through a federally owned corporation. In either case it will need to follow an island-bridge model, performing R&D on an "island" with creative autonomy but tied to the most senior DOE leadership for assistance with research and political support.

6) Energy R&D is underfunded based on the technology needs now apparent; we need to expand the federal R&D portfolio in energy. An ARPA-E will need to operate at large scale to achieve success in helping to transform our energy technology

menu.

7) An ARPA-E should not be established unless the available R&D funding is adequate to the size of the energy technology development task.

8) New energy technology will not be a short-term project; any new program in this area, such as an ARPA-E, should maintain a long-term focus.

This article draws on W.B. Bonvillian's testimony before the House Committee on Science & Technology, Subcommittee on Energy and Environment, on H.R. 364 (ARPA-E legislation)(April 26, 2007); Comments to the House Committee on Science and Technology on ARPA-E Legislation (April 2, 2007); "Power Play," The American Interest (Nov.-Dec. 2006), 38-49, http://www.the-american-interest.com/ai2/article.cfm?Id=183&MId=6 ; and from a pending article on transitioning new energy technologies.

[1]National Academy of Sciences, National Academy of Engineering, Institute of Medicine. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academies Press, 2007), 152-158.

[2]See H.R. 364 as reported by the House Committee on Science and Technology (110th Congress, 1st Sess.); S. 761 as passed by the US Senate, Sec. 2005 (110th Cong. 1st Sess.); House Committee on Science Hearings on ARPA-E Concept (March 9, 2006; April 26, 2006).

[3]Warren Bennis and Patricia Ward Biederman, *Organizing Genius: The Secrets of Creative Collaboration* (Basic Books, 1997), 196-218.

[4]See, generally, Michael Froomkin, "Reinventing the Government Corporation," *1995 Ill. Law Rev.* 543 (1996); John Deutch, "What Should the Government Do to Encourage Technical Change in the Energy Sector?" Report 120 (MIT Joint Program on the Science and Policy of Global Climate Change, May 2005).

[5]Daniel Kammen and Gregory Nemet, Reversing the Incredible Shrinking Energy R&D Budget, Issues in Science and Technology (Fall 2005)

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The views expressed are his own and not necessarily those of MIT.