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A Model for Innovation: ARPA-E Merits Full Funding

BY MATT HOURIHAN AND MATTHEW STEPP | JULY 2011

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Driving growth through innovation isn't just about boosting science funding and hoping for the best. Institutions matter. In the past, public agencies like the Defense Advanced Research Projects Agency (DARPA) and private entities like Bell Labs helped develop and spur economy-changing innovations, most notably the Internet. Their high-risk/high-reward bets created new industries and yielded massive economy-wide returns on initial investment—some of the best "bang for the buck" imaginable. In the energy innovation space, the Advanced Research Project Agency-Energy (ARPA-E)—the Department of Energy's (DOE) breakthrough clean technology R&D program—is beginning to fill this same role.

In many ways, it represents public-private innovation at its finest, both for what it does and how it does it: this is not your grandfather's politicized bureaucracy. It's a fresh and nimble organization that operates at the intersection of fundamental and applied research, bringing science research and technology development together under one roof. And we're already beginning to see early returns: ARPA-E projects, worth approximately $360 million in public funding, have to date obtained $285 million in follow-on private investment and led to 17 patent filings, and the program is still very young. But ARPA-E has only just started to spur successful innovation—and we have yet to see what this innovation engine can really do.

As such, Congress has chosen the right course in creating and sustaining it, authorizing funding at $300 million or more in prior legislation, and so far defeating attempts to de-fund or otherwise eliminate it in order to cut the federal budget. But the battle for adequate ARPA-E funding is far from over. The recent House appropriations bill limits

ARPA-E's funding to just $180 million for FY 2012. While not a small sum, it is far below what experts have recommended. Limited resources will mean more limited recruitment of talented program managers, reduced institutional dynamism, and fewer game-changing breakthroughs. And the proposed budget levels could very well set ARPA-E on the wrong long-term trajectory, reducing America's capacity for public-private energy innovation exactly when we need to be accelerating it. Once innovative capacity is lost, it's hard to regain.

Therefore, Congress should substantially increase ARPA-E's current funding levels for FY 2012 to at least $300 million in order to continue accelerating technological innovation and spurring economic growth.

ARPA-E IS A COMPLEMENT, NOT A SUBSTITUTE, TO OTHER PUBLIC AND PRIVATE SECTOR RESEARCH

In its mere two-year existence, ARPA-E has compiled an enviable track record. Still, a common critique of ARPA-E is that it is duplicative of private sector R&D programs and that, in a time of budget austerity, ARPA-E only siphons off funds for basic research and other public sector programs. Some even go so far as to assume that all public support for innovation is politicized, and thereby ARPA-E must be the same. These critiques miss the point. ARPA-E is not a substitute to other DOE research programs. Nor does it displace private sector investment. Instead, ARPA-E is filling an entirely different "investment gap" than DOE's Office of Science, the federal labs, other energy R&D programs and private energy innovation funding.

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It is widely demonstrated that the private sector tends to under-invest in R&D for several reasons. The benefits of early-stage research projects are often long term, while shareholder and competitive pressures demand payoffs in the short term. The results of a business's R&D are often acquired and used by competitors to improve their own products and processes even when the original firm patents its inventions. This "spillover" effect prevents a business from capturing the full return on its investment and serves as a deterrent to making the investment. Lastly, the private sector is often unwilling to invest in high-risk/high-reward projects because of long-term uncertainty in outcomes. Given a choice, businesses prefer to make less-risky technology choices.

This "risk gap" is even more prevalent in the energy sector. Even the venture capital community, with its generally higher tolerance for risk, has shied away from potentially significant work in the clean energy arena. While venture capital investment in clean technology has spiked in recent months, the investment has focused on later-stage companies. Meanwhile, there has been a decline in funding for earlier-stage, higher-risk technologies, such as those pursued by ARPA-E.[1] Exacerbating these challenges is the problem of scale: The International Energy Agency (IEA) estimates that global investment will need to increase by 400 percent over the next two decades to address our energy challenges.[2] Late stage-limited funding by the venture capital community cannot fill this need by itself.

To fill this underinvestment gap in energy, government supports an array of basic research and R&D programs like the DOE Office of Science and the federal labs, often with bipartisan support. But even though all these programs fall under the R&D umbrella, they aim to achieve different goals. DOE's Office of Science performs more basic, fundamental research; the technology offices in the Office of Energy Efficiency and Renewable Energy and elsewhere are much more focused on applied research. As we describe below, ARPA-E enters the intersection between basic and applied research, bringing fundamental understanding and goal-driven applied research and technology development under one roof. Because ARPA-E's work does not duplicate these programs, reducing its budget will not leave more funding for these programs. Rather, cutting ARPA-E's funding would drain vital public support from a unique program that addresses a specific market failure and provides needed new capacity in energy technology research and development.

Further, ARPA-E is the antithesis of politicized funding, as we discuss below. Decisions on which projects are funded are rigorously merit based, incorporating hard-headed go/no-go assessments on all projects.

THE DARPA BLUEPRINT: SPURRING INNOVATION

In occupying the terrain it does, ARPA-E is, of course, following in the footsteps of DARPA. More specifically, DARPA operates in what is known as "Pasteur's Quadrant," where fundamental science crosses paths with goal-oriented applied research. This approach has yielded significant technological leaps forward in fields like information technology and the global positioning system (GPS)—but just as importantly, it has produced a model that demonstrates how government can successfully and quickly support the development of experimental technologies that can change the world economy.

Given its success, it's no wonder that DARPA was seen as a fitting blueprint for ARPA-E. The Norm Augustine-chaired National Academies' panel—which originally put the idea on the map—recognized not only the interconnectedness of economic well-being and energy security, but also the massive technological challenges preventing a domestic clean energy transformation anytime soon. Appropriately accelerating innovation required a dynamic institution up to the challenge. Enter the DARPA model. In the words of the Augustine panel, "Perhaps no experiment in the conduct of research and engineering has been more successful in recent decades."[3]

So what is this model? There are a few key elements that have made DARPA successful over the years, and are making ARPA-E successful now.[4] These elements can be broken down into three categories: *talent, teamwork* and *technology*.

INVESTMENT IN ARPA-E: FULFILLING THE THREE KEYS

Recruiting and Building Talent

ARPA-E has built and sustained an impressive network of experts from which to draw staff and project participants. Many ARPA-E staff are top experts in their field, with commercial experience at large firms, start-ups, venture capital funds, and at leading research laboratories and universities. ARPA-E program staff are often seen as the "rock stars" of clean energy technology. Of current projects, 40 percent are led by researchers at top universities, with an additional 31 percent led by small businesses and startups.

However, because ARPA-E staff are temporary, with only 3-4 year terms, the agency must constantly recruit new talent. The challenge in maintaining such a roster of experts should be obvious. A major draw for them is that ARPA-E is at the forefront of some of the most exciting—and challenging—technical quests across the energy landscape. A constrained budget environment could throw cold water on this work, making it unclear whether new staff will have the resources to attack problems fully or whether they could choose the projects they believe are most promising. As it is, ARPA-E was never intended to be a huge agency—the original National Academies recommendation stated the eventual goal should be a $1 billion annual budget down the road. A $100 million dollar budget, as originally proposed in the House, would make ARPA-E smaller than the average venture capital fund by a third, and be just a small investment compared to energy industry revenue.[5] The House's last-minute funding increase to $180 million certainly helps, but is still not enough. Convincing visionary venture capitalists at dynamic firms or top researchers with secure laboratory or academic positions to leave their current posts to work on the most challenging energy problems for three years becomes harder with fewer and more uncertain resources.

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Utilizes a Culture of Teamwork and Collaboration

One of the factors in DARPA's success was that program managers made connections between researchers in various fields and in various institutions, allowing knowledge-sharing that would otherwise not happen easily.[6] ARPA-E plays the same role. Program managers hold workshops that bring together the best and brightest experts from academia, the private sector, and government to discuss and debate energy problems that require the most support. From these workshops, program managers propose new programs aimed at a specific technology problem and then put it through an additional round of intense debate among all of ARPA-E's program management. After feedback, refinement, and ultimately the director's approval, ARPA-E solicits a funding opportunity announcement for project proposals for each program. Proposals are then subject to an in-depth peer review process that includes external input from leading technologists, engineers, and scientists. A key characteristic of this process is that the peer review doesn't occur behind closed doors in a smoke-filled room. Instead, applicants read reviewer comments and provide a rebuttal that program managers take into account when making funding choices.

Strikingly, ARPA-E received over 3,700 project proposals for its first six programs after its initial solicitation almost two years ago, representing a groundswell of high risk, innovative clean energy ideas. But because of limited resources, ARPA-E funded only 3 percent of these projects.

ARPA-E has extended this culture of teamwork and collaboration to other government agencies and businesses. For instance, ARPA-E is a key partner in DOE's SunShot initiative—a collaboration of DOE's solar technology research programs—to significantly drive down the total system costs of solar energy. As a result of this collaboration, ARPA-E recently announced the Solar Agile Delivery of Electrical Power Technology Program (Solar ADEPT) to spur breakthroughs in power conversion technology to increase the energy efficiency of solar panels.

ARPA-E has also forged key partnerships with the Department of Defense (DOD) and the private sector to create avenues for deploying and commercializing new technologies. In 2011, ARPA-E built off of the Memorandum of Understanding signed by the DOD and DOE and struck a deal with the Navy to collaboratively develop two energy storage projects vital to the military powering outposts, bases, and ships without fossil fuels.[7] And earlier this year, ARPA-E began partnering with Duke Energy and the Electric Power Research Institute (EPRI) to facilitate demonstration projects, testing, and deployment of successful ARPA-E projects. As a result, projects may have a future path towards future utility-scale implementation of their technologies.

Significantly Advances Vital Clean Energy Technologies

Even with limited resources since its initial appropriation, ARPA-E's talent and teamwork are already making significant advances:

Bringing the App Store to the Energy Sector

Consumer electronics, electric cars, the smart grid, and other IT-enabled devices will continue to revolutionize the way we use electricity. But another needed high-tech revolution in the power sector will be largely unseen by consumers: the use of power electronics—the switches, transistors, and substation platforms that facilitate electricity to end users. ARPA-E's Agile Delivery of Electrical Power Technology (ADEPT) program aims to create power electronics of the 21st century that make them smaller, less costly, smarter, and more energy efficient.

Revolutionizing the Re-emerging U.S. Auto Industry and Making it a World Leader Once Again

Batteries are the biggest reason why electric vehicles are more costly and their performance more limited than that of gasoline-powered vehicles. Without significantly cheaper batteries that can travel up to 500 miles on a single charge, electric vehicles may never be a reality. The Batteries for Electrical Energy Storage in Transportation (BEEST) program is researching and demonstrating the next generation of batteries including lithium-air and ultra-capacitors that can hold more than 5 times the charge at a fraction of the cost of traditional lithium batteries. Recently, an ARPA-E-funded start-up called 24M Technologies received $10 million in venture capital funding for its game-changing flow

battery, nicknamed "Cambridge Crude" for its use of an energy storage paste that can be pumped into the battery.

Growing the U.S. Coal Industry in a Clean Energy Future

Carbon capture and sequestration (CCS) is the ultimate near-zero-carbon bridge technology. If cost effective, CCS technologies would allow the continued use of coal fired power plants without their harmful carbon emissions. And so far, the Innovative Materials and Processes for Carbon Capture Technologies (IMPACCT) program has accelerated the development of innovative carbon capture methods. For example, ARPA-E-funded Codexis, Inc. has forged collaboration with power equipment manufacturers to quickly develop and demonstrate new catalysts meant to capture carbon dioxide at low cost and low energy use to produce the chemical solvents.

Reinvigorating U.S. Agriculture

Agriculture-based biofuels are limited by two processes: the small amount of energy captured by photosynthesis and inefficient conversion of plant mass into fuel. Whereas the Electrofuels program aims to create biofuels from sources that don't rely on photosynthesis, the Plants Engineered to Replace Oil (PETRO) program aims to create more energy-robust, farm-ready crops that convert much more energy than traditional fuel-source plants. Any single breakthrough from this program would result in biofuels that are much cheaper than fossil fuels and be a significant boost to U.S. farmers.

Reducing the Trade Deficit and Reliance on Foreign Materials

Clean energy technologies such as wind and energy storage currently rely on expensive rare-earth materials to function properly. As a result, two problems persist. First, as demand for clean energy technologies increases, so will the price of these materials, making clean energy less cost-competitive. Second, most of these materials are exported from only a few foreign countries, most prevalently from China, which exacerbates the U.S. trade deficit and continues our reliance on foreign countries for energy technologies. The Rare Earth Alternatives in Critical Technologies for Energy (REACT) program aims to spur alternative technology substitutes of rare-earth materials that are affordable and don't perpetuate our reliance on foreign sources.

CONCLUSION: ARPA-E IS VITAL AND GOVERNMENT AT ITS BEST

ARPA-E is critical to jumpstarting the development and commercialization of groundbreaking clean energy ideas. Already, ARPA-E investments have directly accelerated technology R&D and helped private sector investors overcome traditional risk aversion. This is spurring the formation of new companies, the development of new patents, and the creation of new jobs. In fact, the first round of successful projects has received over $100 million in private sector support based on only $24 million in ARPA-E funding, representing great "bang-for-the-buck."[8] And this doesn't count the enormous potential societal benefits from these innovations in terms of reduced oil imports, higher productivity, less pollution, and cheaper energy. Cutting ARPA-E's budget would thwart future successes. A smaller budget would mean fewer projects, a more narrow range of risky projects, more hesitation to explore uncharted areas, and fewer opportunities to attract

private sector interest. Ultimately, reducing ARPA-E's funding will stifle clean technology development and hinder new business start-ups and job creation.

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With that in mind, the debate in Congress has missed the point. Instead of how low can ARPA-E's budget go, Congress should be debating how close to recommended levels it can get. The National Academies recommended a steady ramping up of ARPA-E's funding over five years to eventually hit $1 billion per year. At a time when advances in clean energy technology are urgently needed, Congress risks going in the wrong direction. A good first step would be to fund ARPA-E at $300 million, in line with its current authorization. Even in a time of large budget deficits, it doesn't make sense to slow down one of America's innovation engines. ARPA-E has provided a much needed boost to energy innovation, and it's time to double down those efforts for the long term.

ENDNOTES

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4. For two good discussions on what elements make the DARPA model successful see William B. Bonvillian, "Power Play," The American Interest, December 2006, http://www.the-american-interest.com/article.cfm?piece=183 and Erica Fuchs, "The Role of DARPA in Seeding and Encouraging New Technology Trajectories: Pre- and Post- Tony Tether in the New Innovation Ecosystem," Industry Studies Working Paper, 2009, http://isapapers.pitt.edu/73/.
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ABOUT ITIF

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