TESTIMONY OF WILLIAM B. BONVILLIAN
Director, MIT Washington Office, before the Subcommittee on Energy and Environment, Committee on Science and Technology,
Hearing on "Establishing the Advanced Research Projects Agency-Energy (ARPA-E) - HR 364,"
April 26, 2007 at 2:00 p.m.

Mr. Chairman, Ranking Member Inglis, Members of the Subcommittee:

I appreciate the opportunity to speak with you today. I should note the outset that the views I express today are my own, and I am not speaking for my employer, MIT. I ask that my Comments to the Committee submitted on April 2nd elaborating on this issue be included in the hearing record.

THE ENERGY TECHNOLOGY CHALLENGE:

Energy is a high-stakes problem with much hanging in the balance – energy security and resource dependency on the Middle East, climate change, economy-wide shake-downs from high cartel-imposed prices, disruptive trade imbalances, and macroeconomic trade costs.[1] In response, some have called for a Manhattan Project for new energy technology, or for the equivalent of the Apollo Moon Mission. But those famous technology development projects were focused on single technologies to be stood up in comparatively short-term multi-year projects. They were simple compared to the energy technology challenge. The technologies launched then were for a single customer with the deepest pockets, for the government sector, not for deeply imbedded, stratified and highly competitive private sector markets. Energy challenges require a very different development model in which a complex mix of energy technologies must evolve over decades into the private sector. As some have noted, there will be no short-term energy silver bullet.

An array of new energy technology is needed. Some of these technologies have been tested at economic scale and are ready for demonstration and implementation, others require breakthrough research, still others both breakthroughs and large-scale development. These technologies show that a new energy economy is possible if we have the political will to make it happen. A key point is that we will need many strands of technology development in multiple time dimensions; there cannot be a single technology focus. And the technology development system we create will need to consider and retain room for evolving advances over time - there will be next generation batteries and solar but there will be third and fourth generation advances that will displace the first and second generations, so there must be space for promoting both incremental advance and

[1] This testimony draws on points from my Comments to the House Committee on Science and Technology on ARPA-E Legislation (April 2, 2007), from W.B. Bonvillian, Power Play, The American Interest (Nov.-Dec. 2006), pp. 38-49, and from a pending article on transitioning new energy technologies.

disruptive new technologies; technology arterial sclerosis must be avoided. We have a complex systems problem – there will be multiple energy technology pathways that must evolve over time, and each path will be different, although many will have to be complementary. This is perhaps the most complex technology evolution problem the U.S. has ever faced. It makes getting to the moon start to look simple by comparison.

THE TRANSLATIONAL MODEL FOR ENERGY TECHNOLOGY INNOVATION:

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 in this bridgebuilding, on the innovation "front end" by support for R&D, and on the "back end" by supporting technology prototyping and initial market creation, largely though its pervasive role in the defense technology sector.

The most successful model, as the Subcommittee is aware, for bridging the gap between research and innovation, for moving from the front end close to back end, in the U.S. innovation system has been the Defense Advanced Research Projects Agency (DARPA), established by President Eisenhower in 1957. While DARPA has played many roles over many years, its most important role is sometimes described as working "right-left." DARPA represented a change from the "basic science only" model of most U.S. R&D agencies and aimed for a "connected" model that bridges the "Valley of Death," reaching between research and late stage technology development up to the prototyping stage. In other words, DARPA has connected the stages in the U.S. R&D pipeline that traditionally have been institutionally separated and has put R&D and technology on a continuum. It has done this by following the "right-left" model – deciding up front on a breakthrough technology that must be achieved on the right side of the innovation pipeline, then reaching back to the left side of the pipeline to seek the most promising breakthroughs in science that must be found and nurtured to get there. This is the opposite of the curiosity-driven-research-without-regard-to-technology-objective that dominated the ethos of most U.S. fundamental science agencies. To borrow a phrase from MIT's President Susan Hockfield, for science 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 stood up and implemented. As Erich Bloch, President Reagan's famed NSF Director, once pointed out, research that collects dust on a shelf is not worth much to our society. DARPA's role has been in nurturing technology to make sure it gets off the shelf. A DARPA-like translational "connected science" technology development role is not currently performed at DOE; there is an institutional gap there. Given the need for breakthrough energy technologies and transitioning them – and this is truly the grand technology challenge of our time - this is arguably an institutional gap that should be considered. This would be the central mission of an ARPA-E.

Let me emphasize that an ARPA-E cannot impose technology solutions on the private sector. Its role will be to expand the options, and reduce the technology stand-up

barriers and risks, for private sector firms. It will need to work with the private sector to evaluate what the energy technology leverage points are, what technology paths could have maximum impact, and collaboratively explore and nurture technology opportunities.

CAPTURING THE DARPA CULTURE – THE HYBRID MODEL AND THE DARPA RULESET:

The key to DARPA's success has been its innovative culture. A DARPA clone will not work unless it is able to build a strong innovation culture. DARPA provides some important lessons. A key has been its creation of "hybrid" collaborative teams, combining the best university researchers on the research side with outstanding firms (usually startups, 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 more readily crossing the "Valley of Death." DARPA also competes its research, 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 research base working on energy R&D if we are to have the breakthroughs we need; a competitive hybrid model is a way to achieve this.

Let me emphasize that you can't legislate culture – but you can put management guidance into legislation, encourage an ARPA-E to hire from those with translational research experience (basic research background is not enough), and find researchers who have stood up or worked in innovative companies and know how to bridge R and D. It is important, too, for Congress to exercise strong oversight, particularly at the time of standup. It should also be pointed out that it takes two to translate – the Administration is going to have to affirmatively want to do this and to do it right for it to work.

Other rules from the DARPA ruleset that create its culture and are relevant to an ARPA-E include:

- *Keep it small and flexible*: DARPA consists of only 100–150 professionals; some have referred to DARPA as "100 geniuses connected by a travel agent."
- *Çreate a flat non-hierarchical organization*.
- *Allow the entity autonomy and freedom from bureaucratic impediments*: DARPA operates outside the complex and slow government hiring process and standard government contracting rules, which gives it unusual access to talent, plus speed and flexibility in organizing R&D efforts.
- *Hire an eclectic, world-class technical staff.*
- *Create outstanding teams and networks among its researchers*.
- *Ensure in hiring both continuity and change*: DARPA's technical staff are hired or assigned for 3-5 years. Like any strong organization, DARPA mixes experience and change. It retains a base of experienced experts that know their way around DoD, but rotates most of its staff from the outside to ensure fresh thinking and perspectives.
- *Place leadership in the hands of outstanding program managers*: In DARPA's words, "The best DARPA Program Managers have always been freewheeling zealots in pursuit of their goals." The DARPA director's most important job historically has been to

recruit highly talented program managers and then empower their creativity to put together great teams around great advances.

- *Emphasize acceptance of failure and willingness to take risk.*
- *Set an orientation to revolutionary breakthroughs in a connected approach*: DARPA historically has focused not on incremental but radical innovation. It emphasizes high-risk investment, moves from fundamental technological advances to prototyping, and then hands off the production stage.
- *Create a mix of connected collaborators from a range of disciplines*.

OTHER ORGANIZATIONAL MODELS:

The Subcommittee requested that I review several other organizational models for ARPA-E.

Wholly Owned Government Corporation: For all innovation entities in the business of standing up new technologies, historically the best model has been to put them on a protective island free to experiment apart from contending bureaucracies, but to ensure a strong bridge back to overall organization leaders prepared to defend the entity. If ARPA-E is not housed in DOE, an alternative option is to make it a wholly-owned government corporation entirely outside of DOE.[2] Government corporations appear best at pursuing limited programs of limited visibility that do not tangle with major interests or other parts of the national power structure; ARPA-E will likely have a much more prominent role because of the importance of energy as a national issue. Programs housed in government corporations that reach high levels of visibility can flounder without strong connections to national leadership. If a government corporation model is selected for ARPA-E, a connection to the government leadership could be attempted by naming the Secretary of Energy as chairman of its board with government control of the board.

Locating ARPA-E in a government corporation assures more hiring flexibility, and competitive salary structures more comparable to the private sector, than if it is a DOE entity. It also frees the entity from sometimes slow-moving government procurement requirements. (DARPA offsets these problems by specific legislative authorities, which could be authorized for ARPA-E.)

In-Q-Tel: In-Q-Tel was established in 1999 as an independent, not-for-profit corporation to help the CIA find, obtain and deploy new technologies. In-Q-Tel attempts to act as, in effect, a venture capital firm, making equity investments in and contracting with IT technology firms that have advances In-Q-Tel views as promising. Although financial return is not its priority, it can produce investment gains when a company in its portfolio matures and exits through a buy-out or IPO; gains must be reinvested in new firms with new technologies. In-Q-Tel believes its model gives it a flexibility that traditional government contract approaches do not allow, to gain from the fast pace of developments in the IT and related technology fields.

[2] See, generally, Michael Froomkin, Reinventing the Government Corportion, 1995 Ill. Law Rev. 543 (1996)

Because In-Q-Tel is small it can't really be accused, despite the financial positions it takes in emerging firms, of affecting markets and "picking winners and losers." If an ARPA-E, is stood up and acquires funding comparable to DARPA's, however, it would be operating at a far larger scale and its market interventions could affect competitive outcomes. This could be a problem. In addition, while In-Q-Tel is operating in a very dynamic largely IT sector with new technologies rapidly emerging from firms, that is not the situation with new energy technology. ARPA-E, therefore, would not have such a fertile seedbed to operate in. An ARPA-E also cannot really take the late stage venture capital-type approach In-Q-Tel uses because it needs to nurture breakthrough technology from an earlier R&D stage. While In-Q-Tel can focus on technologies already being stood up in companies, ARPA-E can't; it needs to back R&D, not to simply tilt later stage prototyping, late stage design, and products, as In-Q-Tel does. In-Q-Tel's model is interesting for the tasks it faces, but the potential funding scale of an ARPA-E could be viewed as overly interventionist in energy technology if it was organized like In-Q-Tel, and it faces a breakthrough technology R&D mission not a late stage mission like In-Q-Tel. The technology needs in the two sectors, energy and intelligence, don't allow the models to match.

Skunkworks: A third model would be a skunkworks, an engineering term that describes a group separated out of an overall organization that is left largely autonomous and free of bureaucratic constraints to build advanced technology prototypes and products. The most famous example is aircraft designer Kelly Johnson's skunkworks at Lockheed which created such famous aircraft as the P-80 Shooting Star, the U-2, the SR-71 Blackbird, and the F-117 Stealth Fighter. IBM's rapid stand up of its original PC also followed a skunkworks model. However, the skunkworks concept traditionally has been aimed at the engineering stage not the breakthrough translational research stage that an ARPA-E would also need to pursue. The traits of autonomy and freedom from bureaucratic controls are also inherent in the DARPA model.

HSARPA: The Science Committee, working with the Senate Committee on Homeland Security and Governmental Affairs, previously authorized a DARPA model in the context of the Homeland Security Science and Technology Directorate. While the Committee provided HSARPA with a strong and flexible authorization closely modeled on DARPA's strengths, HSARPA has never been adequately utilized or implemented. It currently exists as a shell with a minimal budget. While a talented initial staff was 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 and instead was closely controlled by a budget and policy bureaucracy within the S&T Directorate that limited HSARPA's funding and effectively made all R&D investment and award decisions. The failure to implement HSARPA as authorized illustrates several points. An innovation culture is critical to success, and legislation alone can't create this unless the implementing agency shows real leadership, supports the new R&D mission, and is determined to use flexible statutory authorities create a strong entity. An ARPA-E will need its own budget and the ability to control it, and not take its funding from other competitor agencies which will dispute the diversion. It will need technical talent of great skill who also have experience at the helm of government R&D entities so can work with other agency bureaucracies. And it will

need 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 over any implementation of an ARPA-E.

THE NEED TO OPERATE AT SCALE:

The energy sector is a trillion dollar sector. A modestly funded R&D effort will not drive transformational shifts in this sector, one of the largest in our economy. Federal energy R&D has fallen by more than half since a high point in 1980, and private sector energy R&D similarly fell. These levels of R&D expenditure compare poorly to other major federal R&D efforts (the Manhattan Project, the Apollo Project, the Carter-Reagan Defense buildup, and NIH Doubling),[3] which in many ways were simpler and more straightforward from an economic standup basis than the complex technology focus for energy. Without significantly improved investment, we will not meet our need for energy technology advance, despite our energy security and climate challenges. We are not going to get there on the cheap.

R&D will not be the most expensive aspect of launching new energy technologies – research is low cost compared to the costs of prototyping 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 to the complexity of DARPA's task. DARPA's budget of $3 billion a year, provides a rough benchmark of a range an ARPA-E should reach, after an initial phase in period. ARPA-E will need to operate at scale or it will not be taken seriously by the best potential researchers or by talented potential employees. Unless appropriators as well as authorizers are prepared to find generous start-up funding for ARPA-E on a bipartisan basis, the entity simply will not work.

If an effective macro-pricing system for carbon, such as a cap and trade program, is adopted by the U.S. because of climate change concerns, this program could, depending on how structured, generate revenues of up to many billions each year, as a carbon permitting system is put in place. Although this macro-pricing step is still likely some years away, when adopted it will not work unless there is a strong innovation system foundation placed under it. Much of these new revenues will be needed for R&D and to leverage large scale industry transition to non-CO2 emitting energy systems. It is important that innovation system reforms be adopted now if these future resources are to efficiently and soundly invested in new technologies. ARPA-E is potentially part of that innovation institution story.

SUMMARY OF KEY POINTS:

1) Standing up new energy technologies is a major and complex challenge, perhaps the most difficult technology stand-up challenge we have faced. Ever.
2) There is a gap in the federal innovation institutions for energy around translational research. There is a need for new institutional arrangements to evolve and

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

transition new breakthrough technologies. An ARPA-E modeled on DARPA could help fill that gap.

3) If an ARPA-E entity is formed its performance will require high performance from outstanding new research entrants, following the DARPA hybrid model of outstanding 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 ruleset that have created an effective culture there.
5) ARPA-E could be stood up either inside DOE or outside it, through a federally owned corporation. In either case it will need to follow an island-bridge model, performing R&D on an island creative autonomy but tied to the most senior DOE leadership who can assist on research and political support.
6) Energy R&D is underfunded based on the technology needs we now see; 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 stood up unless R&D funding is available adequate to the significant size of the energy technology development task. The Committee should seek assurance for Appropriations funding and Executive Branch policy support if this program is to work well.
8) New energy technology will not be a short-term project. The program should maintain a long-term focus.