SHOULD CONGRESS ESTABLISH "ARPA–E," THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY?

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

SECOND SESSION

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March 9, 2006

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SHOULD CONGRESS ESTABLISH "ARPA–E," THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY?

THURSDAY, MARCH 9, 2006

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

SHOULD CONGRESS ESTABLISH ``ARPA-E,'' THE ADVANCED RESEARCH PROJECTS AGENCY-ENERGY?

Thursday, March 9, 2006

10:00 AM – 12:00 PM
2318 Rayburn House Office Building

Witness List

Dr. Steven Chu
Director of Lawrence Berkeley National Laboratory

Dr. David Mowery
William A. & Betty H. Hasler Professor of New Enterprise Development at the Haas School of Business, University of California at Berkeley

Ms. Melanie Kenderdine
Vice President, Washington Operations, for the Gas Technology Institute

Dr. Frank L. Fernandez
President of F. L. Fernandez, Inc

Dr. Catherine Cotell
Vice President for Strategy, University and Early Stage Investment at In-Q-Tel

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Should Congress Establish "ARPA–E," the Advanced Research Projects Agency–Energy?

THURSDAY, MARCH 9, 2006
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, March 9, 2006, the House Committee on Science will hold a hearing on whether Congress should establish an Advanced Research Projects Agency in the Department of Energy, or an ARPA–E.

The National Academy of Sciences, in its report last fall on enhancing American competitiveness, *Rising Above the Gathering Storm,* recommended the creation of an ARPA–E to fund "transformational research that could lead to new ways of fueling the Nation and its economy," and different bills have been introduced in the House and Senate to implement the recommendation.

Critics of the proposal have raised a variety of issues, including that an ARPA–E may not address the actual barriers to new energy technology; that it is based on a research agency model that does not apply well to energy; that different proponents of ARPA–E describe different missions for it; that it would compete with, or get swallowed up by existing energy research programs; and that it is unclear how it would be distinct from other energy research programs.

The hearing is intended to help Congress analyze the arguments for and against an ARPA–E, to consider alternative approaches, and to determine how to structure an ARPA–E if it were created.

2. Witnesses

Dr. Steven Chu is Director of Lawrence Berkeley National Laboratory. He served on the NAS panel[1] that recommended establishing ARPA–E. He was a co-winner of the 1997 Nobel Prize in Physics.

Dr. Catherine Cotell is Vice President for Strategy, University and Early Stage Investment at In-Q-Tel. The Central Intelligence Agency established In-Q-Tel in 1999 to gain access to new technologies emerging from small startup companies.

Dr. Fernando L. Fernandez is President of F.L. Fernandez, Inc., a consulting firm with clients in research and development. He served as Director of the Defense Advanced Research Projects Agency (DARPA) from 1998 to 2001.

Ms. Melanie Kenderdine is Vice President, Washington Operations, for the Gas Technology Institute. She served as Director of the Office of Policy in the Department of Energy from 1999 to 2000.

Dr. David Mowery is the William A. & Betty H. Hasler Professor of New Enterprise Development at the Haas School of Business, University of California at Berkeley. He is an expert in technological change, international trade, and U.S. technology policy.

3. Overarching Questions

- What problems within the energy research enterprise is ARPA–E intended to address? Is ARPA–E the best mechanism to address these problems? If not, what alternatives might be more successful?

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[1] Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology which produced the October 2005 NAS report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* The National Academies Press, Washington, DC (2005).

- If Congress were to create an ARPA–E, how should the agency operate, where in the Department of Energy (DOE) should it be located, and how should it interact with existing aspects of DOE, including the National Laboratories?

4. Brief Overview

The October 2005 NAS report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (also known as the Augustine Report for its chair, retired Lockheed Martin CEO Norman Augustine), recommended creating an ARPA–E within DOE to fund "transformational research that could lead to new ways of fueling the Nation and its economy." The report offered recommendations in four areas to enhance U.S. competitiveness: K–12 education, higher education, economic and technology policy, and scientific research.

The Augustine report argued that affordable and reliable energy production is central to the future of the American economy and that revolutionary new technologies are needed for a sustainable energy future. The report argued further that no existing DOE programs were well suited to promote such technological advances and get them into the marketplace. What was needed, the report concluded was a DOE unit modeled on the Defense Advanced Research Projects Agency (DARPA), the agency that is widely credited with the development of the Internet. The Augustine report said ARPA–E:

> would sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship, where risks and potential payoffs are high, and where success could provide dramatic benefits for the Nation. ARPA–E would accelerate the process by which research is transformed to address economic, environmental, and security issues. It would be designed as a lean, effective, and agile—but largely independent—organization that can start and stop targeted programs based on performance and ultimate relevance.

Citing the Augustine report, the President has proposed increased funding for three research and development (R&D) agencies and for several science and math education programs. The Administration has not endorsed the ARPA–E proposal and has expressed concern that its funding could compete with higher priorities, including proposed increases for DOE's Office of Science. Energy Secretary Samuel Bodman has suggested that an entity based on In-Q-Tel, a venture capital organization sponsored by the Central Intelligence Agency (CIA), might be a more appropriate approach to getting new technology into the energy market. (More on that below.)

5. Issues

The arguments for ARPA–E are laid out in the Augustine report (excerpt attached). This section summarizes the arguments of critics.

Why aren't more revolutionary technologies finding their way into the energy market, and is ARPA–E an effective approach to solving that problem? This is really two questions: First, is the problem in the energy markets primarily one to be solved by increasing the supply of energy technologies or by creating more demand for energy technologies? And second, if the problem is the supply of technologies, would ARPA–E be the most effective way to spawn new technologies and get them into the marketplace?

Is the problem primarily one of technology supply or demand? While there is no question that R&D is necessary to supply new technologies to the marketplace, some critics of the ARPA–E proposal argue that the U.S. energy marketplace is not short of ideas or technologies, but that the current market structure does not generate demand for new technologies. For example, an NAS study several years ago identified numerous existing technologies that could increase automobile fuel mileage that were not being applied or applied for that purpose. Even today, oil prices are generally at a level that does not induce consumers to switch to new energy technologies. Without government incentives, whether through taxes, regulations or other means, the market will not create a sufficient demand for new technologies, these critics argue. They point out that while there are societal reasons to seek new energy technologies, those do not translate into individual demands with oil at current prices. Under this reasoning, new technologies funded by an ARPA–E are no more likely to find their way into the marketplace than are existing ideas.

What is the primary barrier to technology supply and would ARPA–E address it? But even if one assumes that technology supply is part of the problem, ARPA–E, may not be the most effective tool to get more new technologies into the

marketplace, critics argue. According to the Augustine report, ARPA–E would fund "a broad portfolio of foundational research that is needed to invent transforming technologies that in the past were often supplied by our great industrial laboratories." This assumes that a primary gap in energy technology creation is a lack of early-stage, largely basic research and that the government would be able to determine what kind of research in that area is most needed. But many advocates of a greater government role in energy technology see the primary barrier not at the early stages of research, but later in the process when the inventors of new technologies find that they do not have the wherewithal to fully develop their ideas into products or to bring their ideas to market. Some advocates of ARPA–E who were not on the Academy panel argue that ARPA–E could address this stage of the problem, but that is not what the Academy has argued. Critics argue that if the goal is to work on the later stages of development and product introduction, then an ARPA–E is the wrong tool to use.

Does the DARPA model match the needs of energy R&D? Proponents of new government efforts to get R&D into the marketplace often turn to DARPA as a model. For example, in the competitiveness debates of the 1980s, some argued for the creation of a civilian equivalent of DARPA to counter Japanese inroads in U.S. technology markets. (This proposal contributed to the creation of the Department of Commerce's Advanced Technology Program.) In the Homeland Security Act, Congress created a Homeland Security Advanced Projects Agency (HSARPA) to help create new technologies to counter terrorism. HSARPA is not generally viewed as a success, partly because it has focused primarily on short-term development projects.

The appeal of the DARPA model is clear. DARPA has had an enviable record of success in funding technologies that have given the U.S. military a technology edge, many of which have eventually made it into the marketplace. Experts generally attribute the agency's success to its relative independence from the military services and their laboratories, its ties to industry as well as academia, its relative insulation from politics which has enabled the agency in the past to undertake long-range projects and tolerate failure, and its internal structure which empowers program managers to make decisions on who and what to fund. Like the National Science Foundation (NSF), DARPA performs no research, but funds research elsewhere. Unlike NSF, DARPA works more with industry and does not have peer review of its proposals. But DARPA has had its ups and downs and has focused on different aspects of technology over its almost 50 years of operation. Today, DARPA is focusing more on shorter-range projects of more immediate use to the military.

Critics of the ARPA–E proposal argue that a salient feature of DARPA is that it funds the creation of technologies for which the government will be the primary or sometimes sole market. This makes it easier to determine what technologies to target, helps researchers target their own efforts, and assures industry that there will be a payoff for its efforts. Moreover, price is not generally a significant consideration for technologies developed by DARPA. This is true in the area of homeland security, as well. But this fundamental feature of DARPA is not true in the energy arena. Critics argue that it is at best unclear how a DARPA model would succeed in a field in which the government is not a primary customer and does not exert much direct control over the marketplace.

What other models exist that could be applied to energy research? Another model that has been suggested to push more technology into the energy market is In-Q-Tel, a Congressionally created, government-funded non-profit venture capital firm that seeks to accelerate market introduction of products that could benefit U.S. intelligence efforts. In-Q-Tel generally does not get involved in technologies until they are well on their way to development or in the prototype stage. Therefore, In-Q-Tel would not help attack the problem that the Augustine report identified, a lack of early-stage, more fundamental research. But an In-Q-Tel model might get more ideas out of the laboratory and into the marketplace. However, In-Q-Tel, like DARPA, works in a realm in which the government is the market. While In-Q-Tel will only back ventures that appear to have a market beyond the government, its primary goal is to promote the development of products that the government itself will purchase. Also, In-Q-Tel, which was created in 1998 and did not get fully underway until later, does not yet have much of a track record and no one has analyzed how it might function in the energy market. Moreover, the expanding use of government-funded firms that get equity in private companies could raise questions about the appropriate government role in the financial marketplace.

Why can't existing DOE programs accomplish the goal of an ARPA–E and how would an ARPA–E interact with existing programs? Proponents of

ARPA–E argue, in effect, that the DOE Office of Science programs are too basic and that the DOE energy supply programs are too applied, leaving a gap. The Office of Science does support fundamental research, but most of it is not directed at specific energy problems or technologies. (The Office of Science is trying to increase its involvement in these areas.) The applied programs tend to fund incremental research that is unlikely to lead to "transformational" advances. DOE also has a more bureaucratic culture than DARPA and lacks some of DARPA's more flexible procurement authority.

Some critics argue that DOE should reform its basic and/or applied programs to address any gaps identified by the Academy report. Others fear that if an ARPA–E is located in DOE it will be gradually come to look like existing DOE programs because otherwise it will compete with them for funds. These critics are particularly fearful that ARPA–E will simply become another source of funding for the National Laboratories, which they see as too removed from the marketplace and too focused on their existing portfolios to undertake "transformational" research targeted at new energy technologies. These critics note that a strength of DARPA has been that is has not had its own laboratories and has generally worked independently of the military laboratories.

How would an ARPA–E be structured? The Academy panel did not provide detailed advice on how to structure ARPA–E, other than to point to the DARPA model. In establishing an ARPA–E, Congress would have to decide where in DOE to locate it, how to ensure the independent and program manager-driven agenda of DARPA, how to provide stable and adequate funding and how to clearly describe the kinds of research that ARPA–E would be intended to fund. The Augustine report recommends having ARPA–E report to the DOE Under Secretary for Science (a position created by last summer's Energy Policy Act), but critics worry that that would not give ARPA–E adequate independence and would increase the likelihood that funds would go to the National Laboratories. Some critics argue that if Congress were to create an ARPA–E, it should do so outside of DOE and perhaps as a free-standing quasi-governmental entity.

6. Additional Background

Augustine Report. The Academy panel did not receive outside advice or testimony on the ARPA–E idea and at least one of its members was a reluctant supporter of the idea because of concerns that the DARPA model did not apply to areas in which the government was not a customer. Also, the one member of the Academy panel from the energy industry, Lee Raymond, then-Chairman and CEO of the ExxonMobil Corporation, dissented from the recommendation, arguing against further government involvement in energy markets.

History and Structure of DARPA. DARPA's mission is "to prevent technological surprise to the U.S., but also to create technological surprise for our enemies,"[2] through radical innovation to further national security. While each service branch conducts its own research to further known, short-term requirements, DARPA aims to anticipate future military needs, in any service branch, and accelerate development of breakthrough technology to meet those needs.

DARPA was created in 1958 as the Advanced Research Projects Agency (ARPA), in response to Cold War concerns such as the launch of Sputnik Early areas of research involved space and missile defense. By the late 1970's, the agency focused on defense, emphasizing breakthrough technological applications and enhanced links to real customers. ARPA/DARPA research projects include crucial contributions to development of stealth aircraft, unmanned aerial vehicles (UAVs), and the Internet.

DARPA exists within the Office of the Secretary of Defense, outside the service branches. Its director oversees Offices (eight of them at present) that bring together experts with similar interests. Within the Offices are program managers hired for short stints, typically four to six years. Only one layer of management, the Office directors, separates the program managers from the director. DARPA upper management devise research themes in consultation with defense leaders, and together with the program managers, they identify important, difficult problems that fit in with those themes. Program managers are expected to consult with technical communities throughout government, industry, and academia to design projects intended to create novel military capabilities. Program managers have special contracting authority that allows them to negotiate flexible contracting arrangements

[2] *DARPA: Bridging the Gap; Powered by Ideas,* Defense Advance Research Projects Agency, Feb. 2005, p. 1.

with researchers. Their projects aim to create usable products, and must include plans for transfer of those products to real users. The short-term of program managers creates a supply of new people with new ideas and encourages accelerated execution of projects. DARPA has no laboratories of its own—all work is performed by contract with outside researchers—minimizing institutional interests within DARPA that might prolong research that is no longer promising.

DARPA strives to transfer its research products to actual warfighters. This transfer may occur for research that leads to a component technology—such as a stealth technology or microchip—that a defense contractor incorporates the component into larger system that it ultimately sells to a service branch. Because DARPA relies on outside research laboratories, the contractor itself may have participated in the development of the technology, acquiring enough familiarity and confidence in it to use it in a real product it sells to a service branch.

The transfer of technology from DARPA to a service branch may be more challenging, however, for a more elaborate technology. The technology might compete with a significant existing technology already in use by a service. Furthermore, because DARPA looks beyond known, short-term, technological needs, its technology may demand new methods for employing the technology. As a result, a service branch may resist acquiring the DARPA technology. To overcome this resistance, DARPA can appeal directly to the Secretary of Defense, since its position within DOD does not require reporting through the service branches.

History and Structure of In-Q-Tel. In-Q-Tel started off making investments primarily in the information technology area, including Internet security, data integration, imagery analysis, and language translation, and in recent years has expanded into infrastructure priorities such as wireless communications and nanotechnology, and biodefense products such as sensors. These investments have helped government agencies keep up with technology developments in the commercial marketplace, and helped the intelligence community in particular to mold, develop and deploy crucial technologies in a timely manner.

To keep up with the boom in innovations in the private sector, especially in information technology (IT), the CIA assembled a team of senior staff and outside consultants and lawyers in 1998 to design an entity to partner with industry in accelerated solutions to IT problems facing the intelligence community. After meeting with investment bankers, venture capitalists, entrepreneurs, and Members of Congress and staff, the team conceived what is now In-Q-Tel.

In-Q-Tel actively seeks out emerging technology that can help meet the needs of its intelligence agency clients. Its primary means of involvement with fledgling technologies is to invest in the companies developing the technology alongside of commercial investment partners, using the equity tool, combined with a great deal of contractual flexibility, to provide In-Q-Tel and its government partners early access to the technology and the ability to influence product development.

Small or newer companies often do not to target the Federal Government market because it can be difficult to target or slow to access. And because those companies often need to penetrate their markets quickly to generate cash flow, government customers can miss the chance to influence product development. Moreover, private venture capital firms sometimes discourage small companies they invest in from doing business with the government because the complexity of the procurement process and long lead time on procurement decisions. This means that agencies are often two to three years behind the commercial market for technology, especially in areas like IT where there is rapid innovation.

Through special flexibility in contracting arrangements granted by Congress similar to the flexibility enjoyed by DARPA in its arrangements, In-Q-Tel is able to overcome procurement obstacles and to help the intelligence agencies adopt technology more quickly. However, in the long run, In-Q-Tel believes that the products it invests in should be targeted at a commercial market, to lower costs for its client agencies, and that they should be purchased through normal procedures once fully commercialized.

A Board of Trustees oversees In-Q-Tel's direction, strategy, and policies.[3] In-Q-Tel is managed by a CEO and has a staff of 64. Its current budget is estimated to be $60 million.[4] In-Q-Tel seeks to demonstrate solutions. It does not generate finished products. The CIA or other intelligence agencies acquire products through their own

[3] Among its trustees is Norman Augustine, chair of the committee that produced the NAS *Rising Above the Gathering Storm* report. In an August 15, 2005 *Washington Post* article, Augustine called In-Q-Tel "far more successful than [he] thought it would be," but "still an unproved experiment."

[4] "Tech Entrepreneur Joins CIA's Venture Capital Arm," *Washington Post,* January 4, 2006. *http://www.washingtonpost.com/wp-dyn/content/article/2006/01/03/AR2006010301401.html*

separate contracting arrangements. Although In-Q-Tel operations are public and few of their staff have security clearance, the manner of actual use of their products by the CIA may be classified. Nonetheless, In-Q-Tel offers the CIA a mechanism by which to involve industry in solving the specific technology problems faced by the intelligence community.

7. Legislative Proposals

H.R. 4435 (Gordon): A bill to provide for the establishment of the Advanced Research Projects Agency–Energy

This bill establishes the Advanced Research Projects Agency–Energy (ARPA–E) within DOE. This new agency is modeled after DARPA. Under the bill, ARPA–E is headed by a Director appointed by the Secretary. The Director hires program managers to manage individual projects, and the project managers are given flexibility in establishing R&D goals for the program. Program managers will also be responsible for selecting projects for support as well as monitoring their progress. The ARPA–E will have authority to hire specialized science and engineering personnel to be program managers. Participation in the program is limited to institutions of higher education, companies or consortia of universities and companies, and these consortia may also include federally funded research and development centers.

In addition, the bill establishes an Energy Independence Acceleration Fund, allows for recoupment of funds from successful commercialization projects, and includes provisions relating to an Advisory Committee and evaluation of ARPA–E.

S. 2197 (Domenici/Bingaman/Alexander/Mikuski): Protecting America's Competitive Edge through Energy Act of 2006, known as the "PACE-Energy" Act

Section 4 of this bill, which will be marked up on March 8, creates ARPA–E, using language based on the law that created the Homeland Security Advanced Research Projects Agency. Under the bill, ARPA–E is a new office within DOE that will report to the Under Secretary for Science.

S. 2196 (Clinton/Reid/Bingaman): Advanced Research Projects Energy Act

This bill establishes the Advanced Research Projects Agency–Energy within the Department of Energy. The provisions of this bill also include prizes for advanced technology achievements, annual reporting requirements, and authorizations.

8. Witness Questions

Dr. Steve Chu, Dr. Fernando L. Fernandez, Ms. Melanie Kenderdine, and Dr. David Mowery

1. Should ARPA–E be designed more to foster directed basic research or to get products into the marketplace? If the focus were basic research, what steps would ARPA–E or other entities have to take to affect the marketplace? If the focus were technology transfer, what specific barriers would ARPA–E be designed to overcome, how would it do so, and would that be the most effective way that government could transform the energy marketplace?
2. What kinds of entities should receive funding from ARPA–E? Should the National Laboratories be able to receive funding from ARPA–E? How should the work funded by ARPA–E differ from work funded under existing DOE basic and applied research programs? How could Congress structure ARPA–E to ensure that ARPA–E did not end up carrying out programs that are substantially similar to those already in DOE's portfolio?
3. Is it credible to develop a solution to U.S. energy needs based on the Defense Advanced Research Projects Agency (DARPA), given that DARPA is developing ideas for a market in which the government itself is the primary customer and cost is not a primary concern?

Dr. Catherine Cotell

1. How far along in the research and development process are the products and processes that In-Q-Tel supports? To what extent has government research funding contributed to the products and processes that In-Q-Tel supports? How would you contrast In-Q-Tel's role with that of the Defense Advanced Research Projects Agency (DARPA)?
2. To what extent do you think the In-Q-Tel model could be applied to areas in which the government is not going to be a primary or early user of a tech-

nology? What practical and/or philosophical questions would such an expansion of the In-Q-Tel model raise?

3. What have you found to be the primary barriers to new technologies coming to market? Does the U.S. seem to have more of a problem creating new technologies or bringing them to market? Do you think the same factors are the primary barriers in the energy market?

Appendix 1

ARPA–E Proposal Excerpted from Rising Above the Gathering Storm

ACTION B-5: Use DARPA As a Model for Energy Research

The federal government should create a DARPA-like organization within the Department of Energy called the Advanced Research Projects Agency-Energy (ARPA-E) that reports to the under secretary for science and is charged with sponsoring specific R&D programs to meet the nation's long-term energy challenges.[5]

[5] One committee member, Lee Raymond, shares the alternative point of view on this recommendation as summarized in Box 6-3.

Perhaps no experiment in the conduct of research and engineering has been more successful in recent decades than the Defense Advanced Research Projects Agency model. The new agency proposed herein is patterned after that model and would sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship, where risks and potential payoffs are high, and where success could provide dramatic benefits for the Nation. ARPA–E would accelerate the process by which research is transformed to address economic, environmental, and security issues. It would be designed as a lean, effective, and agile—but largely independent—organization that can start and stop targeted programs based on performance and ultimate relevance. ARPA–E would focus on specific energy issues, but its work (like that of DARPA or NIH) would have significant spinoff benefits to national, State, and local government; to industry; and for the education of the next generation of researchers. The nature of energy research makes it particularly relevant to producing many spin off benefits to the broad fields of engineering, the physical sciences, and mathematics, fields identified in this review as warranting special attention. Existing programs with similar goals should be examined to ensure that the Nation is optimizing its investments in this area. Funding for ARPA–E would begin at $300 million for the initial year and increase to $1 billion over five years, at which point the program's effectiveness would be reevaluated. The committee picked this level of funding the basis of on its review of the budget history of other new research activities and the importance of the task at hand.

The United States faces a variety of energy challenges that affect our economy, our security, and our environment (see Box 6–4). Fundamentally, those challenges involve science and technology. Today, scientists and engineers are already working on ideas that could make solar and wind power economical; develop more efficient fuel cells; exploit energy from tar sands, oil shale, and gas hydrates; minimize the environmental consequences of fossil-fuel use; find safe, affordable ways to dispose of nuclear waste; devise workable methods to generate power from fusion; improve our aging energy-distribution infrastructure; and devise safe methods for hydrogen storage.[6]

ARPA–E would provide an opportunity for creative "out-of-the-box" transformational research that could lead to new ways of fueling the Nation and its economy, as opposed to incremental research on ideas that have already been developed. One expert explains, "The supply [of fossil-fuel sources] is adequate now and this gives us time to develop alternatives, but the scale of research in physics, chemistry, biology and engineering will need to be stepped up, because it will take sustained effort to solve the problem of long-term global energy security."[7]

Although there are those who believe an organization like ARPA–E is not needed (Box 6–3), the committee concludes that it would play an important role in resolving the Nation's energy challenges; in advancing research in engineering, the physical sciences, and mathematics; and in developing the next generation of researchers. A recent report of the Secretary of Energy Advisory Board's Task Force on the Future of Science Programs at the Department of Energy notes, "America can meet its energy needs only if we make a strong and sustained investment in research in phys-

[6] M.S. Dresselhaus and I.L. Thomas. Alternative energy technologies. *Nature* 414(2001):332–337.

[7] *Ibid.*

ical science, engineering, and applicable areas of life science, and if we translate advancing scientific knowledge into practice. The current mix of energy sources is not sustainable in the long run."[8] Solutions will require coordinated efforts among industrial, academic, and government laboratories. Although industry owns most of the energy infrastructure and is actively developing new technologies in many fields, national economic and security concerns dictate that the government stimulate research to meet national needs. These needs include neutralizing the provision of energy as a major driver of national security concerns. ARPA–E would invest in a broad portfolio of foundational research that is needed to invent transforming technologies that in the past were often supplied by our great industrial laboratories (see Box 6–5). Funding of research underpinning the provision of new energy sources is made particularly complex by the high cost, high risk and long-term character of such work—all of which make it less suited to university or industry funding.

Among its many missions, DOE promotes the energy security of the United States, but some of the department's largest national laboratories were established in wartime and given clearly defense-oriented missions, primarily to develop nuclear weapons. Those weapons laboratories, and some of the government's other large science laboratories, represent significant national investments in personnel, shared facilities, and knowledge. At the end of the Cold War, the Nation's defense needs shifted and urgent new agendas became clear—development of clean sources of energy, new forms of transportation, the provision of homeland security, technology to speed environmental remediation, and technology for commercial application. Numerous proposals over recent years have laid the foundation for more extensive redeployment of national laboratory talent toward basic and applied research in areas of national priority.[9]

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[8] Secretary of Energy's Advisory Board, Task Force on the Future of Science Programs at the Department of Energy. Critical Choices: Science, Energy and Security. Final Report. Washington, DC: U.S. Department of Energy, Oct. 13, 2003, p. 5.

[9] Galvin Panel report, *Task Force on Alternative Futures for the Department of Energy National Laboratories,* Secretary of Energy Advisory Board. Washington, DC.: U.S. Department of Energy, Feb. 1995; PCAST, *Federal Energy Research and Development for the Challenges of the Twenty-First Century,* Report of the Energy Research and Development Panel, the President's Committee of Advisors on Science and Technology, Washington, DC, Nov. 1997; Government Accounting Office. *Best Practices: Elements Critical to Successfully Reducing Unneeded RDT&E Infrastructure.* USGAO Report to Congressional Requesters. Washington, DC: GAO (?), Jan. 8 1998.

BOX 6-3
Another Point of View: ARPA-E

Energy issues are potentially some of the most profound challenges to our future prosperity and security, and science and technology will be critical in addressing them. But not everyone believes that a federal program like the proposed ARPA-E would be an effective mechanism for developing bold new energy technologies. This box summarizes some of the views the committee heard about ARPA-E from those who disagree with its utility.

Some believe that such applied energy research is already well funded by the private sector—by large energy companies and, increasingly, by venture capital firms—and that the federal government should fund only basic research. They argue that there is no shortage of long-term research funding in energy, including that sponsored by the federal government. DOE is the largest individual government supporter of basic research in the physical sciences, providing more than 40% of associated federal funding. DOE provides funding and support to researchers in academe, other government agencies, nonprofit institutions, and industry. The government spends substantial sums annually on research, including $2.8 billion on basic research and on numerous technologies. Given the major investment DOE is already making in energy research, it is argued that if additional federal research is desired in a particular field of energy, it should be accomplished by reallocating and optimizing the use of funds currently being invested.

It is therefore argued that no additional federal involvement in energy research is necessary, and given the concerns about the apparent shortage in scientific and technical talent, any short-term increase in federally directed research might crowd out more productive private-sector research. Furthermore, some believe that industry and venture capital investors will already fund the things that have a reasonable probability of commercial utility (the invisible hand of the free markets at work), and what is not funded by existing sources is not worthy of funding.

Another concern is that an entity like ARPA-E would amount to the government's attempt to pick winning technologies instead of letting markets decide. Many find that the government has a poor record in that arena. Government, some believe, should focus on basic research rather than on developing commercial technology.

Others are more supportive of DOE research as it exists and are concerned that funding ARPA-E will take money away from traditional science programs funded by DOE's Office of Science in high-energy physics, fusion energy research, material sciences, and so forth that are of high quality and despite receiving limited funds produce Nobel-prize-quality fundamental research and commercial spin offs. Some believe that DOE's model is more productive than DARPA's in terms of research quality per federal dollar invested.

Introducing a small, agile, DARPA-like organization could improve DOE's pursuit of R&D much as DARPA did for the Department of Defense. Initially, DARPA was viewed as "threatening" by much of the department's established research organization; however, over the years it has been widely accepted as successfully filling a very important role. ARPA–E would identify and support the science and technology critical to our nation's energy infrastructure. It also could offer several important national benefits:

- Promote research in the physical sciences, engineering, and mathematics.
- Create a stream of human capital to bring innovative approaches to areas of national strategic importance.
- Turn cutting-edge science and engineering into technology for energy and environmental applications.
- Accelerate innovation in both traditional and alternative energy sources and in energy-efficiency mechanisms.
- Foster consortia of companies, colleges and universities, and laboratories to work on critical research problems, such as the development of fuel cells.

The agency's basic administrative structure and goals would mirror those of DARPA, but there would be some important differences. DARPA exists mainly to provide a long-term "break-through" perspective for the armed forces. DOE already

has some mechanisms for long-term research, but it sometimes lacks the mechanisms for transforming the results into technology that meets the government's needs. DARPA also helps develop technology for purchase by the government for military use. By contrast, most energy technology is acquired and deployed in the private sector, although DOE does have specific procurement needs. Like DARPA, ARPA–E would have a very small staff, would perform no R&D itself, would turn over its staff every three to four years, and would have the same personnel and contracting freedoms now granted to DARPA. Box 6–6 illustrates some energy technologies identified by the National Commission on Energy Policy as areas of research where federal research investment is warranted that is in research areas in which industry is unlikely to invest.

BOX 6-4 Energy and the Economy

Capital, labor, and energy are three major factors that contribute to and influence economic growth in the United States. Capital is the equipment, machinery, manufacturing plants, and office buildings that are necessary to produce goods and services. Labor is the availability of the workforce to participate in the production of goods and services. Energy is the power necessary to produce goods and services and transport them to their destinations. These three components are used to compute a country's gross domestic product (GDP), the total of all output produced in the country. Without these three inputs, business and industry would not be able to transform raw materials into goods and services.

Energy is the power that drives the world's economy. In the industrialized nations, most of the equipment, machinery, manufacturing plants, and office buildings could not operate without an available supply of energy resources such as oil, natural gas, coal, or electricity. In fact, energy is such an important component of manufacturing and production that its availability can have a direct impact on GDP and the overall economic health of the United States.

Sometimes energy is not readily available because the supply of a particular resource is limited or because its price is too high. When this happens, companies often decrease their production of goods and services, at least temporarily. On the other hand, an increase in the availability of energy—or lower energy prices—can lead to increased economic output by business and industry.

Situations that cause energy prices to rise or fall rapidly and unexpectedly, as the world's oil prices have on several occasions in recent years, can have a significant impact on the economy. When these situations occur, the economy experiences what economists call a "price shock". Since 1970, the economy has experienced at least four such price shocks attributable to the supply of energy. Thus, the events of the last several decades demonstrate that the price and availability of a single important energy resource—such as oil—can significantly affect the world economy.

SOURCE: Adapted from Dallas Federal Reserve Bank at www.dallasfed.org/educate/everyday/ev2.html.

Box 6-5: The Invention of the Transistor

In the 1930s, the management of Bell Laboratories sought to develop a low-power, reliable, solid-state replacement for the vacuum tube used in telephone signal amplification and switching. Materials scientists had to invent methods to make highly pure germanium and silicon and to add controlled impurities with unprecedented precision. Theoretical and experimental physicists had to develop a fundamental understanding of the conduction properties of this new material and the physics of the interfaces and surfaces of different semiconductors. By investing in a large-scale assault on this problem, Bell announced the "invention" of the transistor in 1948, less than a decade after the discovery that a junction of positively and negatively doped silicon would allow electric current to flow in only one direction. Fundamental understanding was recognized to be essential, but the goal of producing an economically successful electronic-state switch was kept front-and-center. Despite this focused approach, fundamental science did not suffer: a Nobel prize was awarded for the invention of the transistor. During this and the following effort, the foundations of much of semiconductor-device physics of the 20th century were laid.

BOX 6-6
Illustration of Energy Technologies

The National Commission on Energy Policy in its December 2004 report *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges* recommended doubling the nation's annual direct federal expenditures on "energy research, development, and demonstration" (ERD&D) to identify better technologies for energy supply and efficient end use. Improved technologies, the commission indicates, will make it easier to

- Limit oil demand and reduce the fraction of it met from imports without incurring excessive economic or environmental costs
- Improve urban air quality while meeting growing demand for automobiles
- Use abundant US and world coal resources without intolerable impacts on regional air quality and acid rain
- Expand the use of nuclear energy while reducing related risks of accidents, sabotage, and proliferation.
- Sustain and expand economic prosperity where it already exists—and achieve it elsewhere—without intolerable climatic disruption from greenhouse-gas emissions.

The commission identified what it believes to be the most promising technological options where private sector research activities alone are not likely to bring them to that potential at the pace that society's interests warrant. They fall into the following principal clusters:

- **Clean and efficient automobile and truck technologies**, including advanced diesels, conventional and plug-in hybrids, and fuel-cell vehicles
- **Integrated-gasification combined-cycle coal technologies** for polygeneration of electricity, steam, chemicals, and fluid fuels
- **Other technologies that achieve, facilitate, or complete carbon capture and sequestration**, including the technologies for carbon capture in hydrogen production from natural gas, for sequestering carbon in geologic formations, and for using the produced hydrogen efficiently
- **Technologies to efficiently** produce biofuels for the transport sector
- **Advanced nuclear technologies** to enable nuclear expansion by lowering cost and reducing risks from accidents, terrorist attacks, and proliferation
- **Technologies for increasing the efficiency of energy end use in buildings and industry**.

Chairman BOEHLERT. The hearing will come to order.

I want to welcome everyone to this morning's hearing, which will be the first public balanced discussion of the proposal to establish an Advanced Research Projects Agency in the Department of Energy, or as it has come to be called, "ARPA–E." Given its origin in the National Academy of Science's *"Gathering Storm"* report, the ARPA–E proposal must be treated seriously and respectfully.

But serious and respectful treatment means thinking through all the strengths and weaknesses of the proposal and the alternative ways to achieve the goals of the Academy panel and the sometimes-differing goals of the proposal's other supporters. It does not mean rushing through open-ended legislation with limited analysis or debate.

Parenthetically, let me deviate from the text. There is much—to draw an analogy here. There is much talk in this town about the urgent need for lobbying reform. A hasty rush to judgment on the part of the House, we've solved the problem. We have banned former Members from the gymnasium. Give me a break.

So I intend for the Science Committee to act deliberately, starting with this balanced panel that will enable us to think through such key issues as: why more revolutionary technologies have not made their way into the energy market, the different approaches to getting more technology to market, how an ARPA–E would compare to existing programs, and what characteristics an ARPA–E would have to have to be successful.

Right now, I would describe myself as an open-minded skeptic about ARPA–E. On the one hand, I am immediately drawn to any proposal designed to foster more focused research on energy technologies and a more sustainable U.S. energy portfolio. But on the other hand, I see that the ARPA–E proposal is predicated on several implicit assumptions, all of which are, at the very least, open to debate, and I hope they will be debated here this morning.

I think the four key assumptions are: one, that the problem with the energy market is that the supply of new technologies is insufficient; two, that the supply is constrained because of a lack of fundamental research; three, that a sensible way to promote more fundamental research is to apply the DARPA model to a civilian energy sector; and four, that implementing the DARPA model is the best way to improve energy research, given the tight federal budgets.

Now let me examine each of these assumptions briefly, and I hope our witnesses will examine them as well and, in the process, help educate us.

I think the first assumption is clearly wrong. The biggest barrier to new energy technologies is not supply. It is demand. And until the government is willing to institute policies to stimulate demand or until oil gets to a dangerously high price, it is going to be very hard for new technologies to enter or dominate the new market. We already have plenty of technologies to improve automobile fuel efficiency just sitting on the shelf, gathering dust, to cite one sad example. So I see this whole supply debate as largely beside the point. Until we change the market, developing new technologies is just going to be the equivalent of filling up a warehouse of a com-

pany that is already out of business. But the demand side isn't in our jurisdiction.

But that said, obviously, improving the technology supply wouldn't hurt, but is the supply problem due primarily to a lack of fundamental research or are the problems further down the research pipeline, to use the outdated metaphor? Our witnesses have a range of views on that, which need to be heard.

Similarly, our witnesses differ on the applicability of the DARPA model, and I have to say that I haven't heard a very good explanation of how the DARPA model can be reasonably employed in a situation, unlike in Defense where the government is not the primary or initial customer. For starters, the politics surrounding technology choices are going to be completely different in a commodity market.

And finally, we need to decide whether even if ARPA–E were a good idea whether it would be a better use of funds than granting the President's proposal to increase the DOE Office of Science by 14 percent, because in this budget environment, we surely are not going to be able to do both. And increasing the Office of Science budget was an even higher priority Academy recommendation than ARPA–E.

So we have got some serious, thorny, critical questions before us today that ought to provoke good conversation, not only with those of us on the dais, but among our impressive witnesses as well. And I look forward to hearing what they have to say. What we hear today will be an important factor in deciding how we proceed legislatively over the next couple of months as we prepare the competitiveness legislation to deal with the American Competitiveness Initiative.

Mr. Gordon.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

I want to welcome everyone to this morning's hearing, which will be the first public, balanced discussion of the proposal to establish an Advanced Research Projects Agency in the Department of Energy, or as it has come to be called "ARPA–E." Given its origin in the National Academy of Science's *Gathering Storm* report, the ARPA–E proposal must be treated seriously and respectfully.

But serious and respectful treatment means thinking through all the strengths and weaknesses of the proposal and all the alternative ways to achieve the goals of the Academy panel and the sometimes-differing goals of the proposal's other supporters. It does not mean rushing through open-ended legislation with limited analysis or debate.

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I think the four key assumptions are: One, that the problem with the energy market is that the supply of new technologies is insufficient; two, that the supply is constrained because of a lack of fundamental research; three, that a sensible way to promote more fundamental research is to apply the DARPA (the Defense Advanced

Research Projects Agency) model to the civilian energy sector; and fourth, that implementing the DARPA model is the best way to improve energy research given the tight federal budget.

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But, that said, obviously improving the technology supply wouldn't hurt. But is the supply problem due primarily to a lack of fundamental research, or are the problems further down the research "pipeline" to use that outmoded metaphor? Our witnesses have a range of views on that, which need to be heard.

Similarly, our witnesses differ on the applicability of the DARPA model. And I have to say that I haven't heard a very good explanation of how the DARPA model can be reasonably employed in situations, unlike defense, where the government is not the primary or initial customer. For starters, the politics surrounding technology choices are going to be completely different in a commodity market.

And finally, we need to decide whether, even if ARPA–E were a good idea, whether it would be a better use of funds than granting the President's proposal to increase the DOE Office of Science by 14 percent. Because in this budget environment, we surely are not going to be able to do both. And increasing the Office of Science budget was an even higher priority Academy recommendation than ARPA–E.

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What we hear today will be an important factor in deciding how we proceed legislatively over the next couple of months as we prepare competitiveness legislation.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman, for bringing this group together for a hearing today, and I think you had some very thoughtful remarks and questions that we need to dwell on.

Let me—I want to depart from my statement today and have a conversation with the Majority Members that are here today. I wish there were more, but I know that many of the staffs are here, and others will be coming in.

Let me first start with a brief history, I won't say lesson, but refresher.

A couple of years ago, Senator Lamar Alexander and Senator Bingaman, Chairman Boehlert, and myself asked the Academies of Science to put together a commission to talk about the competitiveness of our country in the 21st century, what would—what could we do about it. The National Academies came together. They brought together some significant CEOs, Nobel laureates, academic individuals, and they came forward with what we know as *"Rising Above the Gathering Storm."* And you might remember that Norman Augustine was the Chairman of that commission and reported to us a few months ago.

I want to read to you just quickly a couple of the statements that he made to us at that hearing.

"It is the unanimous view of our committee that America today faces a serious and intensifying challenge with regard to the future competitiveness and standard of living. Further, we appear to be on the losing path. The thrust of our findings is straightforward. The standard of living of Americans in this and the years ahead

will depend to a very large degree on the quality of jobs that they are able to hold."

Now my wife is out of town, so I am picking up my five-year-old daughter this afternoon. I am going to have to bring her back here, so you may see her on the Floor, but I am very concerned that she, and probably your kids and grandkids, very well—this is not rhetoric, but very well could inherit the first national economy and standard of living that is lower than their parents. You know, this is a very real possibility. And by no misunderstanding, Mr. Augustine laid that out to us.

Now they didn't do a lot of what you might call original research. They didn't do a lot of—plow a lot of new ground. What they did was take the recommendations that had been made over and over and over and just brought them together. And I think it is time that we stop, you know, trying to have new commissions, and it is time to get ready to do something. And with that in mind, the Senate has put together—they took the Augustine recommendations—the legislation—or they took the Augustine report and made it into legislation. Two-thirds of the Senators, an equal amount of Democrats and Republicans, have signed on to that. Two-thirds of the Senators have done that. Now if we were to take that legislation and bring it here to the House, it would go to seven different committees, and you know what that would mean. So Lamar called me a while back and asked me to participate with this. I said of course I would, and we had already been started, but I didn't want to take their exact bill, because it would just get lost over here.

So what I have done is I have taken the bulk of the *"Rising Above the Gathering Storm."* I didn't get into the tax credits and the ways and means stuff. Dr. Thomas thinks he knows what he is doing, and I don't think he wanted recommendations from the Science Committee. There were some patent things that, again, judiciary can handle, but the rest of it, the guts of it was education, investment in research, and the—to a lesser extent, the ARPA–E proposal. I have put those into three different bills. I have sent, I guess, two personal letters for dear colleagues and direct staff contacts with all of your offices.

Now we have, I think, virtually all of the Democrat Science Committee Members on the bills. We have a few Republicans on the bills at large. But let me say, folks, if we can't get together on something that two-thirds of the Senate can, it is going to be a long damn year. And you know, I don't know whether it is going to be next year or it is going to be two years or 10 years, but there is a pretty good chance I am going to be Chairman of this committee. And one of the rules is going to be I don't care, you know, who introduces a bill. A good idea is a good idea, and we need to go forward with it.

And I want to, again, put to your attention these bills today. ARPA–E is a little more controversial. Now we did this in a way that gave the Secretary a lot of flexibility, tried to build it around the DARPA model, and it may not be what everybody wants. The objective is to reduce our energy dependency by 20 percent over the next 10 years. I agree with the Chairman that, you know, conservation is a part of that. You know, I am not a big nuke fan, but

that is a part of it. You know, I am for everything, quite frankly. I think we are going to have to deal with everything.

It is some more controversy, but when it comes to education, science education, there should be no misunderstanding. And what we are going to do, we are going to screw around, if you are not careful, and we are going to see the science education taken away from the National Science Foundation. It is already—you know, that is where it is heading right now. You are going to have something put in the Department of Energy or the Department of Education, and when that happens, it is going to get lost and be poorly managed.

So again, I would like for you to take another look at these bills. You know. We—it was a rough start, but we finally got together on an authorization to NASA. We got an overwhelming vote in the House, and the reason was, I think, that folks were glad to see a bipartisan bill. You know, this could be a bridge not only for good legislation here but bring some camaraderie and civility to the House in general.

So I would, once again, follow up on those two letters for dear colleagues and request that you take a look at this so that we could move forward.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Mr. Chairman, thank you for holding this hearing today to consider the merits of the ARPA–E proposal. This proposal arose from a recommendation by a Committee of the National Academy of Science, National Academy of Engineering and the Institute of Health. The Committee was established at the request of certain Senators and House Members, including Chairman Boehlert and me.

The Academies were asked to look at what actions "federal policy-makers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century." We also asked the Academies to tell us what strategy could be used to implement each of their recommended actions. The result was the Committee's report entitled, *Rising Above the Gathering Storm,* which was released late last year.

I have taken a different approach from the Senate in casting the report's recommendations into legislative language. Rather than introducing a comprehensive package as the Senate did, I have introduced a package of three bills that are primarily in the jurisdiction of the Science Committee. My bills deal with those recommendations in Science Education, and Science and Engineering. The third bill establishes an ARPA–E organization within DOE.

My ARPA–E bill, H.R. 4435, has a very defined goal—to reduce imports of energy from foreign sources by 20 percent within 10 years through the development of transforming energy technologies. The Director of ARPA–E reports to the Secretary. However, the bill provides great flexibility to the Director in structuring and managing the organization to meet the goal.

The *Rising Above the Gathering Storm* Report was very vague in how its proposed ARPA–E would be organized and exactly what it would accomplish. I, too, am flexible in considering how this organization should be put together and how it should accomplish meeting the 20 percent goal. I do worry, however, that overly prescriptive legislation could inhibit the willingness of smart men and women to join ARPA–E and the ability of ARPA–E managers to accomplish whatever goals are ultimately established.

Mr. Chairman, I believe this hearing will be a learning experience for all the Members of the Committee. Today's witnesses will bring us a variety of perspectives on how this organization should be put together and what it should do. I look forward to hearing their testimony today.

Norman Augustine, the Chairman of the Academies Committee, gave the Science Committee this sobering assessment in his testimony last fall: "It is the *unanimous* view of our committee that America today faces a serious and intensifying challenge with regard to its future competitiveness and standard of living. Further, we appear to be on a *losing path*."

I trust that this is only the first of a number of hearings to address how the Nation will remain competitive. All the outside studies we need are complete; now is the time to act—not only on ARPA–E—but on all the other recommendations in this committee's jurisdiction.

I look forward to working with the Chairman as we go forward on this important issue.

I yield back the balance of my time.

Chairman BOEHLERT. Thank you very much, Mr. Gordon. Thank you for your thoughtful commentary.

Let me make a couple of observations in response.

First of all, I couldn't agree more with the Augustine report, and he is, and they are, in the report, absolutely correct. We are on a "losing path" if we do nothing, and that is the sad fact.

But the reality is we are determined to do something, and we have repeatedly indicated not only in response to this issue, but all of the issues that come before this panel, that we will work cooperatively with all Members to take meaningful, decisive action.

Let me point out that in December, we had an innovation summit, which we had captains of industry, like Augustine, university presidents, Cabinet officers to talk about this very important subject of competitiveness. That very morning, I had a meeting in the White House with Josh Bolten, the Director of the Office of Management to once again lay out the compelling case that we had to do more to invest on the part of the government in basic science. We have to do more to improve the performance in K–12 science and math literacy. I was gratified, as I know you were, too, as all of us were concerned about this subject when the President, in his State of the Union message announced the American Competitiveness Initiative. More funding. It put both the—all three, National Science Foundation, which finances most university-based research in this country, the Office of Science at the Department of Energy, and NIST, very valuable agencies, directly in the front lines in this war dealing with competitiveness on a path to double the budget over 10 years. And I said following that State of the Union message to all who asked, that those eloquent words were very important, but they have to be followed by meaningful deeds.

This is a town where a lot of eloquent words are expressed and there is no follow-through beyond the headline and the story of the next day. Two weeks later, there was the follow-through. The eloquent words were followed by meaningful deeds. The budget submitted to Congress and the American people called for billions more in all of the areas of primary concern to you and to me, putting the National Science Foundation, the Office of Science, NIST on a path to double their budget over 10 years with significant increases in the first year, recognizing that we have to pump hundreds of millions of dollars more into science and math education K–12. They have heard our message, "they" being the Administration, the leadership of our government in the Executive Branch. Not only have they heard our message and we have implored them to act, they have heeded the message.

So now we are on a path to do what you and I have worked so hard over the years to encourage them to do. The fact of the matter is that we have to be very thorough and very deliberative as we do this. We have to, as I say, make haste a little bit slowly, but we are determined to move in a significant, meaningful way. And

one of the issues under discussion is the ARPA–E proposal from the *"Rising Above the Gathering Storm"* report. And we want to examine them.

So this is how we work, as you well know, in this committee. We get experts, the foremost experts in our country, on the subject matter being discussed before us, and we thank all of you for being facilitators. And it shouldn't surprise anyone that not every single one of these people agree on the whole package, as presented.

So for thoughtful analysis and commentary, we invite them to have a dialogue with this committee, and we are looking forward to it. And I assure you, Mr. Gordon, and I assure all the Members of this committee, that we are determined to go forward, not next year or next month, but we have got to set the stage. We have got to sort of build the foundation for our action. A lot of the programs that are talked about in *"Rising Above the Gathering Storm"* are already in. Just yesterday, I met with the Chairman of the Appropriations Committee, Mr. Lewis of California, and said you know and everyone knows that the most important thing in this tight budget environment is the allocations you, Mr. Chairman of the Appropriations Committee, give to the individual subcommittees. And there are two subcommittees critically important, one chaired by Frank Wolf of Virginia, the other by David Hobson of Ohio, both of whom are on the same wavelength as we are. And so I said you have got to give them the allocations so that they cannot only embrace what the President is proposing but what we might add on to it. And I had that same message in a meeting yesterday afternoon at the White House. So we are on full alert. All systems are on go, and I look forward to a continuing working partnership with you.

And now I will recognize——

Mr. GORDON. Mr. Chairman, I have two comments. May I—would he yield for——

Chairman BOEHLERT. But the Chairman didn't exceed your time limit, and what I want to do is get—recognize Ms. Biggert so we can have her commentary and then recognize someone on your side. And then we will go to the witnesses, because that is how we are going to learn the most. You and I could talk to each other all day and all night. We have a nice relationship. But let us hear from our witnesses, but first, Chairwoman Biggert.

Ms. BIGGERT. Thank you very much, Mr. Chairman, and thank you for holding this hearing. I—for I know that you share my deep concern for our nation's future energy security. And I am pleased to be working with you to examine this interesting proposal by the National Academies of Science to support transformational research that could lead to new ways of fueling the Nation and its economy. And I—on that goal, I think that all of us agree, and I see no debate.

However, I just don't see how the creation of a new agency and new bureaucracy achieves this goal, even if it is patterned after the famed DARPA. I remain open to the ARPA–E concept, but I will readily admit that I need some convincing.

And why am I so skeptical? Well, let me count the ways.

First, it is not clear what problems we are trying to solve with the creation of an ARPA–E.

Is it a lack of private-sector investment in long-term or basic research? If so, how do we solve the problem by creating a brand new agency to distribute scarce federal resources to companies to conduct research that they wouldn't otherwise conduct? Correct me if I am wrong, but it doesn't—but doesn't the Academy's version of ARPA–E put the Federal Government in the position of picking which companies are winners?

Is it a lack of federal funding for high-risk, transformational research? If so, how would you characterize DOE's current FreedomCAR and Hydrogen Initiatives? How about the President's Global Nuclear Energy Partnership or U.S. participation in ITER, the international fusion experiment? I don't know about my colleagues, but I would put these in a category of high-risk, transformational research.

Is it a failure of the Department of Energy to effectively transfer new energy technologies from the laboratory to the market? If so, wouldn't it make more sense to closely examine the legal and policy obstacles to the transfer of technology from our universities, national laboratories, and other research institutions?

In short, is this a solution in search of a problem?

Second, this proposal to create an ARPA–E is largely based on the mythology of the agencies, namely the myths that DARPA can't do anything wrong and that DOE can't do anything right.

Well, let me just relay a story about what I think is a DARPA failing. A number of scientists in my district developed a way to produce inexpensive, high-quality, titanium powder. You would think any technology to improve the processing or reducing the cost of titanium would be of obvious value to DOD because titanium is strong and lighter than steel.

The scientists took their ideas to DARPA and DARPA turned them down. But they knew that they had a good idea, so they brought the idea to Congressman Bartlett and me. Despite the fact that the Army quickly recognized the transforming potential of this technology, DARPA had to be convinced. Only after the scientists had obtained the private sector capital, built a pilot plant, and demonstrated that the technology worked did DARPA decide to provide a relatively small sum of funding. Now in my book, that is not very high risk.

And how does this story end?

Well, just this week, DOE's National Energy Technology Lab and Boeing, the largest consumer of titanium in the world, joined the Army in my office to discuss plans to rapidly scale-up the technology DARPA rejected in 2003.

And third, we tried to replicate DARPA at the Department of Homeland Security, and did it work? Not according to most accounts. If it didn't work at DHS, why do we think it will work at DOE where the private sector, rather than the government, will be the primary customer?

Finally, I think it is important to note that ARPA–E was one of 20 recommendations in the National Academy of Sciences *"Gathering Storm"* report, and it was the only one not to receive the unanimous support of the Committee. Norm Augustine, who chaired the NAS panel, testified to this fact before the Committee in October of last year. And interestingly enough, opposition came

from the one Member of the Committee with, arguably, the most expertise in energy markets and the energy industry.

As the Chairman of the Energy Subcommittee, I take my responsibility for overseeing the research and development programs at the DOE very seriously. And I think that we need to find the right solutions, not just any solution. If ARPA–E is the right solution, I will support it. But to get to the right solution, we have an obligation to ask tough questions, and I think that is our purpose here today.

I am anxious to hear this distinguished panel and to have them share their insight with us. And I think they represent a wealth of talent and expertise.

And with that, I yield back the balance of my time.

[The prepared statement of Ms. Biggert follows:]

PREPARED STATEMENT OF REPRESENTATIVE JUDY BIGGERT

Thank you, Mr. Chairman, and thank you for holding this hearing, for I know you share my deep concern for our nation's future energy security. I am pleased to be working with you to examine this interesting proposal by the National Academies of Science to support "transformational research that could lead to new ways of fueling the Nation and its economy." On that goal, I see no debate.

However, I just don't see how the creation of a new agency—a new bureaucracy achieves this goal, even if it is patterned after the famed DARPA. I remain open to the ARPA–E concept, but I will readily admit that I need some convincing.

Why am I so skeptical? Let me count the ways. First, it is not clear what problems we are trying to solve with the creation of an ARPA–E.

Is it a lack of private sector investment in long-term or basic research? If so, how do we solve the problem by creating a brand new agency to distribute scarce federal resources to companies to conduct research they wouldn't otherwise conduct? Correct me if I'm wrong, but doesn't the Academy's version of ARPA–E put the Federal Government in the position of picking what companies are winners?

Is it a lack of federal funding for high-risk, transformational research? If so, how would you characterize DOE's current FreedomCAR and Hydrogen Initiatives? How about the President's Global Nuclear Energy Partnership, or U.S. participation in ITER, the international fusion experiment? I don't know about my colleagues, but I would put these in the category of high-risk, transformational research.

Is it a failure by the Department of Energy to effectively transfer new energy technologies from the laboratory to the market? If so, wouldn't it make more sense to closely examine the legal and policy obstacles to the transfer of technology from our universities, national laboratories, and other research institutions?

In short, is this a solution in search of a problem?

Second, this proposal to create an ARPA–E is largely based on the mythology of the agencies—namely the myths that DARPA can't do anything wrong, and that DOE can't do anything right.

Well, let me relay a story about a DARPA failing. A number of scientists in my district developed a way to produce inexpensive, high-quality, titanium powder. You would think any technology to improve the processing or reduce the cost of titanium would be of obvious value to the DOD because titanium is strong and lighter than steel.

The scientists took their idea to DARPA, and DARPA turned them down. But they knew they had a good idea. They brought their idea to Congressman Bartlett and me. Despite the fact that the Army quickly recognized the "transforming" potential of this technology, DARPA had to be convinced. Only after the scientists had obtained private sector capital, built a pilot plant, and demonstrated that the technology worked did DARPA decide to provide a relatively small sum of funding. By my book, that's not very "high-risk."

How does the story end? Well, just this week, the DOE's National Energy Technology Laboratory and Boeing—the largest consumer of titanium in the world—joined the Army in my office to discuss plans to rapidly scale-up the technology DARPA rejected in 2003.

Third, we tried to replicate DARPA at the Department of Homeland Security. Did it work? Not according to most accounts. If it didn't work at DHS, why do we think it will work at DOE, where the private sector—rather than the government—will be the primary customer?

Fourth, where exactly are we going to get the money for ARPA–E? Many of my colleagues here today advocating for the creation of an ARPA–E couldn't stop criticizing the Administration just last month for failing to "adequately" fund such energy programs as energy efficiency and renewable energy. With growing demands on our limited federal resources, is there really "new money" available for this agency? Realistically, no; the money will come from other basic and applied DOE research programs.

Finally, I think it is important to note that ARPA–E was one of 20 recommendations in the National Academy of Science's *"Gathering Storm"* report, and it was the only one not to receive the unanimous support of the Committee. Norm Augustine, who chaired the NAS panel, testified to this fact before the Committee in October of last year. And, interestingly enough, opposition came from the one Member of the Committee with arguably the most expertise in energy markets and the energy industry.

As Chairman of the Energy Subcommittee, I take my responsibility for overseeing the research and development programs at the DOE very seriously. I can't think of anything more important to our national security, our economy, and our standard of living than energy. And I know everyone here is genuinely interested in finding solutions to our nation's energy challenges.

But we need to find the "right" solutions, not just any solution. If ARPA–E is the right solution, I will support it. But to get to the "right" solution, we have an obligation to ask tough questions. That's my purpose here today.

I'm anxious for this distinguished panel to share their insight with us. You represent a wealth of talent and experience, and we are privileged to have you here with us today. Thank you for participating. With that, I yield back the balance of my time.

Chairman BOEHLERT. And let me congratulate the distinguished Chair of the Subcommittee on Energy. She used exactly five minutes, her time.

Now here is the deal. We are told that about 11:20, 11:25, we are going to have just one vote. I hope it is delayed even more, but our hope would be that we could retain the panel, we would dash over to vote, and come right back. And while you are inconvenienced, but you have got a lot that we need to hear. And so—and secondly, the Chair would recognize the Ranking Member of the Subcommittee, who is not here at the time, he has another commitment, and I will then recognize Mr. Gordon to consume that time, but then we want to get to the witnesses.

Mr. GORDON. Thank you, Mr. Chairman. I will be brief. You were generous in your allocation of my time in my opening statement, so let me just follow along on a couple of things I was saying earlier.

After the Chairman's opening remarks, at 90 percent or more of our hearings here, my opening remarks begin with "I agree with the Chairman," which is the case so often on so many things.

But I do feel compelled to point out that it is nice that he has talked to the appropriators, but just spending money doesn't help if you don't get it right. In the President's budget, he dramatically cut, on the way to doing away with, the 50-year program of math and science education in the National Science Foundation. You know, that is bad policy, in my opinion.

We need an authorization. I think we need to move forward here. Two-thirds—I will remind everybody. Two-thirds of the Senate, equally between Democrats and Republicans, have come together in a base bill. And surely, they will make some changes as they go forward, but they had a—it came out of the subcommittee yesterday. So I think it is time for us to take some action.

Now I—the Chairman was very eloquent about the earlier science forum that they had. I will remind you, the Democrats were

not invited to come. There was no effort to put our, hopefully, somewhat thoughtful comments in there.

Now I signed on to a Republican bill yesterday, I do it almost every day, to Duncan Hunter's bill. You have got—you know, we have got three bills before us now. You know. It is time to start working together. You know, we can—it is time to stop studying. This is—again, today is a little more controversial. Certainly, the education bill shouldn't. The train is going to move out if we don't get moving.

Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much.

I want to make sure that we have got a ticket on that train.

I will tell you what I tell my constituents. As you well know from my record, oftentimes my view and my votes are somewhat different from the Administration position, and what I tell my constituents, when you see me differ from the Administration, you can assume the Administration is wrong.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before our committee to discuss the possibility of establishing an Advanced Research Projects Agency (ARPA–E) in the Department of Energy.

The report released by the National Academy of Sciences (NAS) on October 12, 2005 entitled, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* recommended the creation of an ARPA–E to fund research that could lead to new ways of fueling the Nation and the economy. I commend Chairman Boehlert and Ranking Member Gordon for holding this hearing today because the recommendations this report issued will provide our committee with good policy options that ensure new ideas and innovation. I look forward to learning more about APRA–E and how it would be structured.

The second component of the Augustine report focused on ways to enhance America's competitiveness. In June of this year, Chairman Boehlert and Ranking Member Gordon wrote to the NAS to endorse the Senate request for a study of "the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology," to provide advice and recommendations for maintaining U.S. leadership in science and technology in the face of growing global competition. Today, Americans are feeling the effects of globalization because a substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe. It comes as no surprise that high-tech jobs are being outsourced to foreign countries like China and India. Without high-quality, knowledge intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our constituents will face a lower standard of living. I am very concerned about the issue of off-shoring and outsourcing and how these trends will affect current scientists and engineers, as well as the future employment opportunities and career choices of students.

Despite claims to the contrary by the Administration, the federal research and development budget is not faring well, particularly the non-defense component which has been flat for 30 years. In FY07, the Administration proposed a one percent spending reduction in the federal science and technology budget. Reductions like this continue to chip away at the U.S. research base and jeopardize our economic strength and long-term technological competitiveness. Innovation does indeed drive our economic growth, but we must have the research base to drive new energy technologies.

I welcome our panel of witnesses and look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

Our nation is experiencing an energy crisis. America's dependence on oil has begun to cripple its economy.

As demand from developing nations such as China increases, simple economics tell us the price of oil will increase.

More and more money must come out of hard-working Americans' pocketbooks for gasoline, and so they are spending less on other things.

All indicators agree that the price of oil will likely continue to go up. It is becoming more apparent that national leadership will be required to push initiatives forward to lessen our dependence on oil. Alternative fuels should be studied. More efficient engines should be designed. There are many directions to take.

Private industry is not moving as quickly as it needs to be moving in the development of alternative or more efficient fuels and engines. Therefore a proposal has been made by leading research experts at the National Academy of Science for the creation of an Advanced Research Projects Agency within the Department of Energy—ARPA–E.

Ranking Member Gordon has proposed legislation based on the National Academy's recommendation, and I am a co-sponsor.

This hearing comes at an opportune time, as Members of the Science Committee are interested to know the best way such a department would be organized and directed.

I would like to thank our witnesses for being here today. The Committee will undoubtedly have many questions and benefit from your expertise and leadership in cutting-edge research.

It is my hope that this hearing will help us as we provide the leadership necessary to get our energy economy back on track.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

I thank Chairman Boehlert and Ranking Member Gordon for holding this important hearing today, and I thank our distinguished witnesses for making the time to be here.

I've been in enough hearings of this committee to know that most of us on this committee, from both sides of the aisle, are on roughly the same page when it comes to recognizing that our nation is faced with significant energy challenges in the future and that science and technology will play an important role in addressing those challenges.

Where we differ is in the details. Some of us would prefer to see more solar electricity generation, others nuclear, and still others clean coal. Should we focus on hybrids, hydrogen fuel cell vehicles, or liquid fuels produced from non fossil sources? I could go on all day listing all of the options that are probably supported by one member or another of this committee.

The breadth of these short lists makes it clear that how we approach energy in the future is something we need to put a lot of thought into. Are we going to need to focus on research dollars in some very basic areas to generate new knowledge? Should we focus on bringing technologies that have already been invented within DOE labs but which are currently sitting on the shelf into the marketplace? Do we need to provide the private sector with assistance to overcome market failures?

Each of these approaches probably requires a different kind of program or agency to implement it. At this point, we don't know which one we are thinking about, so it is essential that we talk about all of the possibilities. The ARPA–E model is one of those options, and I've co-sponsored Ranking Member Gordon's ARPA–E bill because I think it is an idea we should be talking about. I'll admit that in the wake of a hearing we had about DARPA's current directions in the area of computer science I'm a bit wary of creating another organization like it that might lose its way after being around for a long time, but if we take care we can design ARPA–E to avoid those problems.

I look forward to hearing from our distinguished witnesses today, including my friend and Nobel Laureate Dr. Steve Chu of Lawrence Berkeley National Lab, about their thoughts on the directions we should be taking with our future energy policy.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Let me first thank Science Committee Chairman Boehlert and Ranking Member Gordon for holding this hearing today on the idea of an "Advanced Research Projects Agency for Energy" (ARPA–E). Modeled after the Department of Defense's Defense Advanced Research Projects Agency, the goal of ARPA–E, under Congress-

man Gordon's proposition, would be to reduce U.S. foreign energy dependence by 20 percent over a 10-year period. The idea of ARPA–E is intended to implement the recommendation of the National Academy of Sciences' (NAS) report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.*

The idea of ARPA–E holds great potential, and if done right, the agency could yield great returns in the future. As a Member of Congress who represents Houston, often called the "Energy Capital of the World," I am very interested in this matter. Through the past year, I have been working with many of the companies in an effort to get a better understanding of high gasoline prices and the many disruptions in production caused by Hurricanes Katrina and Rita. These now infamous hurricanes showed how vulnerable this country is to price spikes in our energy costs.

Hurricanes Katrina and Rita, as well as the war in Iraq, increased energy demand from abroad. In addition, a host of other factors have contributed to sky-high oil prices, and increased dependence on oil from abroad. Crude oil prices at one point even exceeded $70 a barrel. Americans suffered greatly from the high cost of gasoline, at one point being forced to pay over $3 a gallon at the pump in many areas. And now that winter has arrived, the price of natural gas, and the subsequent cost of heating one's home, has been exceedingly high.

The problem is further exacerbated when one considers our addiction to foreign oil. In President Bush's latest State of the Union address, he pointed out the United States' addiction to oil.

It is due to these reasons that I am so interested in the possibilities ARPA–E provides. We need a proactive, concerted effort to change the state of our energy policy in the United States today, or things will only get worse. ARPA–E would support high-risk, high pay-off research projects in energy technologies that could lead us to new realms of energy production, usage and efficiency. New and daring research must be conducted in the energy technology field; our economy depends on it, our security depends on it, our independence depends on it, and our environment depends on it. We need to be able to include the energy industry in the forward-thinking research opportunities that ARPA–E will make available. I look forward to the witnesses sharing their visions of an ARPA–E that could actually accomplish these goals.

Thank you Mr. Chairman, I yield the remainder of my time.

Chairman BOEHLERT. Now here we go to our witness list, and a very distinguished panel that we have.

Dr. Steven Chu, Director of Lawrence Berkeley National Laboratory. Dr. Chu, good to have you here. Dr. David Mowery, William A. and Betty H. Hasler Professor of New Enterprise Development at the Haas School of Business, University of California at Berkeley. Dr. Mowery. And Ms. Melanie Kenderdine, Vice President, Washington Operations for the Gas Technology Institute. Ms. Kenderdine. Dr. Fernando Fernandez, President of F.L. Fernandez, Inc. Dr. Fernandez. And Dr. Catherine Cotell, Vice President for Strategy, University and Early Stage Investment at In-Q-Tel, and as someone who has served for the eight years on the Intelligence Committee, I know what In-Q-Tel is.

Dr. Chu, you are first up. Don't be nervous when you see that red light go on. It is an arbitrary—we want you to try to summarize your statements in five minutes or so, but the Chair is a little bit lenient. I mean, we have some of the most distinguished thinkers in our country before us, and I am not going to limit you to 300 seconds. But the shorter your initial presentation is, the longer we have to pick your brains. And boy, that is fertile territory for us.

Dr. Chu.

STATEMENT OF DR. STEVEN CHU, DIRECTOR, LAWRENCE BERKELEY NATIONAL LABORATORY

Dr. CHU. Thank you, Chairman Boehlert, Ranking Member Gordon, Members of the Committee.

I am Steven Chu, Director of Lawrence Berkeley National Laboratory for 11½ years. Before that time, I served at Stanford University in Bell Laboratories for a total of 26 years, and I was the co-winner of the 1997 Nobel Prize in Physics.

I was privileged to serve under Norman Augustine as a member of the committee that produced the report *"Rising Above the Gathering Storm."* And I come before you today as a representative of the Augustine Committee, not the Department of Energy.

I thank you for providing me with the opportunity to contribute to today's discussion on the proposal for Advanced Research Projects Agency-Energy, known as ARPA–E.

The Nation needs to develop clean, safe, secure, sustainable energy for three reasons: our national security is directly linked to energy security; economic competitiveness is intimately tied to how much energy costs and how efficiently it is used; and there are serious environmental concerns associated with energy usage from local pollution to climate change.

Because of these concerns, I believe that the energy problem is the single most important problem that has to be solved by science and technology in the coming decades. At present, there appear to be no magic bullets, and we need to follow a dual strategy. We must improve efficiencies and use our energy more wisely. And I will depart and say that that is primarily a question of regulation, taxes, fiscal policy, and things of that ilk, but we also must develop a diversified portfolio of investments to develop sustainable sources of energy.

The Augustine Committee recommended the establishment of ARPA–E as one of 20 recommendations. They want to provide added opportunities to Department of Energy to develop new technologies to solve the energy problem. We conceived ARPA–E as an organization reporting to the DOE under the Secretary of Science that should achieve four objectives: one, bring a freshness and excitement to energy research that will attract many of our best and brightest minds, especially students and young researchers, including those in the entrepreneurial world; two, focus on creative, out-of-the-box, transformational research that industry cannot or will not support due to its high risk but where success would provide dramatic benefits for the Nation; three, utilize an ARPA-like organization that is flat, nimble, and sparse projects whose promise remains real should be sustained while programs whose promise has faded should be terminated; four, create a new tool to bridge the gaps between basic energy research development and industry innovation.

The agency would perform no research itself but would fund work conducted by universities, start-ups, established firms, and national laboratories, and forge links between these research entities.

Another goal of ARPA–E is to bring teams of the best researchers across departments and schools and to encourage the best and brightest to pursue more applied work than they would normally have pursued. It could also serve as a model of how to improve the transfer of science and technology research in other areas that are essential for our future prosperity.

The Committee considered several models before deciding to use ARPA as a template, and I have indicated in my written testimony why we settled on ARPA as a guide. However, we believe the specific implementation is best determined by policy-makers in Congress and by the Department of Energy.

Funding for ARPA–E would start at $300 million the first year and increase to $1 billion per year over five or six years. And at that point, the program's effectiveness should be evaluated and appropriate actions taken.

It is critical that funding of ARPA–E not jeopardize the basic research supporting the Department of Energy's Office of Science, and I have to inject that I believe that part does do things right.

The Committee's recommendations are prioritized and its top recommendation in the area of research is to increase funding for basic research by 10 percent per year over the next seven years. The Augustine Committee applauds the Administration's American Competitiveness Initiative.

We also applaud the courageous efforts of Secretary of Energy, Sam Bodman, to make basic research activities a high priority in the Department of Energy budget. The Augustine report strongly recommends that support of ARPA–E come from new funding.

I also note that the number one priority of our report is to fix K–12 science and mathematics education.

A critical factor in ARPA–E's success is that funds be used to fund ideas bubbling up from the bottom. By placing ARPA–E under the Under Secretary of Science, the Committee believes that this goal can be reached and the earmarking of funds can be avoided.

What research might be funded by ARPA–E?

Here are some examples.

The development of a new class of solar cells. Photovoltaic solar cells using conventional semiconductor technology are efficient at converting sunlight into electrical energy, but their fabrication costs remain too high. Organic and polymer solar cells can be made at low cost but have poor efficiencies and degrade in sunlight. One promising avenue toward inexpensive, efficient, and long-lasting solar cells is to create novel materials based on four or more elements that can be manufactured with thin-film technologies. Another approach is to create inexpensive, nano-particle devices that can use different nanostructures for the conversion of sunlight into electrical charges and for the collection of those charges. Another avenue worth exploring is to combine photovoltaic electrical generation with novel, biologically-inspired, electrochemistry.

Biomass substitutes for oil. Ethanol for transportation is currently produced from sugar cane, corn, and other plants designed for food. However, the most cost-effective bio-fuels will come from the conversion of cellulose. If done right, bio-fuels produced in America can have the potential of supplying us with enough oil substitutes to eliminate foreign imports. The creation of crops raised for energy will take—also take full advantage of our great agricultural capacity.

ARPA–E can fund the creation of new plants by introducing dozens of genes into existing plants. Recently, a team of scientists at Berkeley Lab inserted many genes into bacteria to produce an extremely effective anti-malarial drug. The Gates Foundation has

given this team $42 million to commercialize this technology at a target cost below 25 cents a cure. Similar technologies can be used to make plants self-fertilizing, drought-resistant, and pest-resistant.

Research on more efficient conversion of cellulose into liquid fuel will yield even greater dividends. Current methods use high temperature, high acid processes that are very energy-intensive. The breakdown of cellulose into ethanol is also accomplished with bacteria or fungi, but this process can be made much more efficient if improved micro-organisms are developed.

I have listed several examples of what might be considered ARPA–E-like research. Many of these ideas cut across disciplines. The potential for ARPA–E, if designed and executed well, will yield tremendous benefit.

Chairman Boehlert, Ranking Member Gordon, and Members of the Committee, thank you for the opportunity to present the National Academy's recommendations before you. It has been a privilege to working together to enable our nation to prosper in the 21st century. I would be glad to respond to questions.

[The prepared statement of Dr. Chu follows:]

PREPARED STATEMENT OF STEVEN CHU

Chairman Boehlert, Ranking Member Gordon, Members of the Committee,

I am Steven Chu, Director of Lawrence Berkeley National Laboratory. Prior to my current job, I was at Stanford University for 17 years and at AT&T Bell Laboratories for nine years. I was the co-winner of the 1997 Nobel Prize in Physics.

I was privileged to serve under Norman Augustine as a member of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine's Committee on Prospering in the Global Economy of the 21st Century that produced the report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* I come before you today as a representative of the Augustine Committee, and not the Department of Energy.

Thank you for providing me with the opportunity to contribute to today's discussion on the utility of the committee's proposal for the Advanced Research Projects Agency–Energy (known as ARPA–E).

INTRODUCTION

We live in a truly magical time. With the flick of a finger, the power of 10 horses flows from a small wire in the wall of our homes to clean our carpets. We go to the local market under the pull of hundreds of horses and fly across our continent with tens of thousands of them. Our homes are warm in the winter, cool in the summer and lit at night. We live well beyond the dreams of Roman emperors.

What has made all of this possible is our ability to exploit abundant sources of energy. The worldwide consumption of energy has nearly doubled between 1970 and 2001. By 2025, it is expected to triple. The extraction of oil, our most precious energy source, is predicted to peak sometime in 10 to 40 years, and most of it will be gone by the end of this century. What took hundreds of millions of years for nature to make will have been consumed in 200 years. We have abundant forms of fossil fuel such as coal, shale oil, and tar sands that will last for hundreds of years. However, in my opinion, if the world substantially increases the generation of greenhouse gases by relying heavily on fossil fuels, we run the risk of causing disruptive climate change.

The Nation needs to develop clean, safe, secure, and sustainable energy for three reasons:

1. Our energy security is directly linked to national security.
2. Economic competitiveness is intimately tied to how much energy costs, and how efficiently it is used.
3. There are serious environmental concerns associated with energy usage from local pollution to climate change.

Because of these concerns, I believe that the energy problem is **the** *single most important problem* that has to be solved by science and technology in the coming decades. At present, there appear to be no magic bullets to solve the energy problem. While efficiencies play a huge role in defining how much energy we consume, we must also have a diversified portfolio of investments to develop sustainable sources of energy.

ARPA–E

The committee that developed the report, *Rising Above the Gathering Storm,* included amongst its 20 recommended action steps, the establishment of the Advanced Research Projects Authority–Energy (ARPA–E).

The committee intends ARPA–E to provide a new field of opportunity to the Department of Energy as it works to develop new technologies to supply this nation and the world, with safe, clean, affordable, secure, and sustainable energy. We simply must find energy supplies that will not degrade our environment. If we do not do this, there will be no future prosperity.

We must take concerted action and make the investments necessary to enlist our most talented researchers and innovators. Our committee, therefore, conceived ARPA–E as an organization reporting to the DOE Under Secretary for Science that can achieve four objectives:

1. Bring a freshness, excitement, and sense of mission to energy research that will attract many of our best and brightest minds—those of experienced scientists and engineers, and, especially, those of students and young researchers, including those in the entrepreneurial world.
2. Focus on creative "out-of-the-box" transformational energy research that industry by itself cannot or will not support due to its high risk but where success would provide dramatic benefits for the Nation.
3. Utilize an ARPA-like organization that is flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programs that do not prove to be as promising as anticipated.
4. Create a new tool to bridge the gap between basic energy research, and development/industrial innovation.

The agency would itself perform no research, but would fund work conducted by universities, start-ups, established firms and national laboratories. Although the agency would be focused on energy issues, it is expected that its work (like that of DARPA or NIH) will have important spin-off benefits, including aiding in the education of the next generation of researchers.

Another goal of ARPA–E is to bring teams of the best researchers across departments and schools to get the best results for the Nation. ARPA–E would provide an incentive to encourage the best and brightest researchers to pursue more applied work than they would normally pursue. It could also serve as a model for how to improve the transfer of science and technology research in other areas that are essential to our future prosperity.

The committee considered several models before deciding to focus on energy and to use ARPA as a template. Among these were In-Q-Tel (which engages the entrepreneurial community with technologies of potential interest to the intelligence community), HSARPA (the Department of Homeland Security Version of ARPA), SEMATECH (a jointly funded research venture of the Federal Government and the semiconductor industry), Advanced Technology Program (ATP), Small Business Innovation Research program (SBIR), Civilian Technology Corporation (recommended in a previous 1992 National Academies report chaired by Harold Brown), and Discovery Innovation Institutes (recommended by a 2005 National Academies report chaired by James Duderstadt).

In-Q-Tel is a fine model for its mission. However, the objective set out by the *Gathering Storm* report is to perform research and to sponsor the early development of transformational new approaches to energy. In-Q-Tel operates in a different context. Its goal is not basic research, but the application of those ideas already in business and to act as a bridge from one industry to another. On the other hand, the goal of ARPA–E is to conduct applied research and to act as a bridge from basic research to development of new technologies.

Also, In-Q-Tel has one customer, the Intelligence Community, with a well-specified set of mission activities that they want to accomplish differently or better. Developing new energy technologies is an earlier-stage, much less focused activity. If ARPA–E is successful, then technology transition will be from the research laboratory to small and large companies, not into the government. Arguments compel the

conclusion that DARPA is better model for ARPA–E where the challenge is to transform U.S. energy dependence.

Three congressional bills, H.R. 4435, S. 2196, and S. 2197 call for the establishment of ARPA–E. Although the National Academies do not endorse legislation, we can say that each of these bills is harmonious with the general principles outlined for ARPA–E in the *Gathering Storm* report. We believe the specifics of implementation are best determined by policy-makers in Congress and at the Department of Energy.

FUNDING OF ARPA–E

Funding for ARPA–E would start at $300 million the first year and increase to $1 billion per year over 5–6 years, at which point the program's effectiveness would be evaluated and any appropriate actions taken.

In funding ARPA–E, it is critical that its funding not jeopardize the basic research supported by the Department of Energy's Office of Science. The committee's recommendations are prioritized and its top recommendation in the area of research is to increase the funding for basic research by 10 percent per year over the next seven years. The Augustine Committee applauds the Administration's American Competitiveness Initiative, particularly the courageous efforts of Secretary of Energy Samuel Bodman, to make basic research activities a high priority in the Department of Energy budget .The Augustine Report strongly recommends the support of ARPA–E come from new funding.

I also note that the number one priority in our report is to fix K–12 science and mathematics education.

A critical factor in ARPA–E's success is that the funds be used as wisely as possible to fund the best ideas. These ideas should bubble-up from the bottom and should not be directed from the top. By placing ARPA–E under the Under Secretary of Science, the committee believes that this goal can be reached and earmarking of funds can be avoided.

WHAT RESEARCH MIGHT ARPA–E FUND?

Some examples of what ARPA–E might fund include:

1. The development of a new class of solar cells.

Photovoltaic solar cells using semiconductor technology can be very efficient at converting sunlight into electrical energy, but the fabrication cost remains too high. Organic and polymer solar cells can be made at low cost, but the efficiencies are low and existing materials degrade in sunlight. One promising avenue towards inexpensive, efficient and long lasting solar cells is to create novel materials based on multiple elements that can be manufactured with thin-film technologies. Another approach is to create nano-particle devices (distributed junction solar cells) that use different nanostructures for the conversion of sunlight into charge carriers and for the collection of those charges onto electrodes.

2. Biomass substitutes for oil.

The ethanol for transportation is currently produced from sugar cane, corn or other plants. However, the most cost effective bio-fuels will come from the conversion of cellulose into chemical fuel. When the fuel is burned, CO_2 is released into the atmosphere, but the overall cycle can, in principle, be carbon neutral. The creation of crops raised for energy will also take full advantage of our great agricultural capacity.

ARPA–E can fund the creation of new plants to be grown for energy by incorporating a number of genes are introduced into plants. Recently, a team of scientists at Lawrence Berkeley National laboratory inserted many genes into bacteria to produce an extremely effective anti-malarial drug. The Gates Foundation has given this team a $42 M grant to commercialize the technology so that the drug can be made available to the developing world. Similar technology can be used to make plants self-fertilizing, drought and pest resistant. Note that about 25 percent of the energy input in growing corn comes from fertilizer, which is made from ammonia derived from natural gas.

Research on more efficient conversion of cellulose into liquid fuel would also yield great dividends. Current methods use the high temperature/high acid processes that are very energy intensive. The breakdown of cellulose into ethanol is also accomplished with bacteria or fungi, but this process can be made much more efficient if the micro-organisms are modified with these methods.

COMMITTEE'S QUESTIONS ABOUT ARPA–E

In your request asking me to testify at this hearing, you asked me to respond to three questions about ARPA–E. I will now address each question.

1) Should ARPA–E be designed more to foster directed basic research or to get products into the marketplace? If the focus were basic research, what steps would ARPA–E or other entities have to take to affect the marketplace? If the focus were technology transfer, what specific barriers would ARPA–E be designed to overcome, how would it do so, and would that be the most effective way that government could transform the energy marketplace?

The purpose of ARPA–E is not to get products into the marketplace, but to conduct the research necessary to transform the energy marketplace by creating platform technologies. ARPA–E would identify and support the science and technology critical to our nation's energy infrastructure and act as the bridge between the basic research, predominantly supported by the Office of Science and the more applied areas.

The committee believes that there are great researchers and great ideas out there which are not currently being utilized to address the Nation's energy challenge. Because the benefits of long-term energy research would accrue to all, it is not necessarily beneficial for one company to make the long-term investment needed for a transformational technology today.

Historically, this role was served by the great industrial labs such as Bell Labs which created devices such as the transistor. In the 1930s, there was a need to develop a low-power, reliable, solid-state replacement for the vacuum tube used in telephone signal amplification and switching. Materials scientists had to invent methods to make highly pure germanium and silicon and to add controlled impurities with unprecedented precision. Theoretical and experimental physicists had to develop a fundamental understanding of the conduction properties of this new material and the physics of the interfaces and surfaces of different semiconductors. By investing in a large-scale assault on this problem, the transistor was invented in 1948, less than a decade after the discovery that a semiconductor junction would allow electric current to flow in only one direction. Fundamental understanding was recognized to be essential, but the goal of producing a vacuum tube substitute was kept front-and-center. Despite this focused approach, fundamental science did not suffer: a Nobel prize was awarded for the invention of the transistor. During this and the following efforts, the foundations of much of semiconductor-device physics of the 20th century were laid.

ARPA–E could fund research at universities start-ups, established firms and national laboratories for similar focused goals. ARPA–E may be especially useful in funding projects whose success will require coordinated efforts from several fields of science. It would also meet the Nation's need for transformational, high-risk, high payoff R&D that would be a challenge for today's electric utilities, petroleum companies, and large energy equipment manufacturers to address and which are not very attractive to the entrepreneurial world.

2) What kinds of entities should receive funding from ARPA–E? Should the National Laboratories be able to receive funding from ARPA–E? How should the work funded by ARPA–E differ from work funded under existing DOE basic and applied research programs? How could Congress structure ARPA–E to ensure that ARPA–E did not end up carrying out programs that are substantially similar to those already in DOE's portfolio?

The research work supported by ARPA–E would fall between DOE's Office of Science and its energy technology programs such as the offices of Energy Efficiency & Renewable Energy, Nuclear Energy, Science, and Technology, Fossil Energy, Electricity Delivery and Energy Reliability. By its nature, ARPA–E would fund activities more applied than DOE basic research programs and too basic for its applied research programs. ARPA–E would also be looking for ways to harness basic science discoveries that are supported by other agencies.

Some key differences between ARPA–E and existing DOE organizations include:

- Small staff of smart, vigorous, creative minds with deep knowledge in relevant research areas hired from the best performing organizations in energy research and advanced energy industry.
- Creative, challenging programs that attract the brightest researchers in industry and the university to work on them.
- Programs designed with no constraint to fund existing organizations.
- Staff would also rotate on a regular basis as is the case at DARPA today to ensure that new ideas are constantly part of the mix. Staff's performance would be evaluated on their basis to identify and support transformative research.

- Programs with clear and challenging goals. For example, the DARPA speech recognition program started with a clearly defined goal such as recognizing a) continuous speech (words not disjointed), b) spanning a 1,000 word vocabulary, c) using conventional microphones, and d) performing recognition in real time.
- Programs defined to perform R&D of the multiple, complementary elements that enable new energy approaches to eventually become commercialized.
- Objective is breakthrough, new workable ideas—not incremental research.
- Flat management.
- Jumpstarts the adoption of a technology by inserting prototypes to demonstrate effectiveness. For example, it was DARPA not the military, that developed the Predator, an unpiloted air vehicle that was used in theatre in the 1990s and greatly accelerated the adoption of such vehicles for surveillance and reconnaissance.
- Merit review of proposals.
- Operates with special authorities that enable the hiring of the needed talent, and that permit the agency to rapidly and nimbly make investments.

The criteria used to select proposals for research funding would be very important. Among them could be criteria that would describe how the proposed research is similar or different from existing research activities that DOE (or other organizations) is funding.

Another critical criteria would be that the research be transformational—not just incremental progress on existing ideas.

Anyone could compete for funding from ARPA–E including universities, industry, businesses, and national laboratories or ideally, a consortia of these organizations. Those managing the process would need to be very independent and not favor one group over another.

3) Is it credible to develop a solution to U.S. energy needs based on the Defense Advanced Research Projects Agency (DARPA), given that DARPA is developing ideas for a market in which the government itself is the primary customer and cost is not a primary concern?

The agency's basic administrative structure and goals would mirror those of DARPA, but there would be some important differences. DARPA exists mainly to provide a long-term "break-through" perspective for the armed forces. As previously stated, DOE already has excellent mechanisms for supporting long-term fundamental research in the Office of Science and shorter-term research in its other branches. ARPA–E would identify and support the science and technology critical to our nation's energy infrastructure by focusing on problem-driven research. It also could offer several important national benefits:

- Promote research in the physical sciences, engineering, and mathematics.
- Create a stream of human capital to bring innovative approaches to areas of national strategic importance.
- Turn cutting-edge science and engineering into technology for energy and environmental applications.
- Accelerate innovation in both traditional and alternative energy sources and in energy-efficiency mechanisms.
- Foster consortia of companies, colleges and universities, and laboratories to work on critical research problems.

Although DOD is the primary direct customer for most successful DARPA-developed technologies, i.e., the military procures the ultimate systems, and devices, DOE would not in this sense be the direct customer for ARPA–E. In other words, it is really the defense industry that is the customer for DARPA who then in turn uses its research to develop products it hopes is useful for DOD. DOD rarely builds products itself. Similarly, the energy industry could use the results of ARPA–E to similarly turn its research to develop technologies for itself, utilities, and the general public.

There are, however, vast potential world markets for successful new technologies that generate and distribute safe, clean, affordable, secure, and sustainable energy. Thus capital for proven technologies should not be a problem and an organization such as In-Q-Tel (which serves as a venture capital firm for the intelligence community) may or may not be necessary.

ARPA–E could be a catalyst to drive technologies into industry. It can take early high risk positions and access a talent base that generally is not available in the

industry. Some ARPA–E projects would be conducted by industry, and would help to expand high-tech capabilities within companies, just as has been the case of DARPA projects in the defense industry.

Our committee did not believe it appropriate for us to specify the organization and mission of ARPA–E in great detail. We believe that must be worked out by the Secretary of Energy and the Under Secretary for Science in consultation with experts from the scientific and engineering communities. Defense visionaries who realized that the military had to reach out to new communities for the technologies that would be required to counter the rapidly changing threats of the post-Sputnik era established the original ARPA in the DOD. It was enormously successful. We believe that ARPA will provide the right general framework on which to design ARPA–E. It is a proven model.

CLOSING COMMENTS

The potential payoff of ARPA–E through engaging new researchers, exciting a new generation to confront the looming energy crisis, and operating with an agility to involve scientists and engineers who otherwise might not contribute to meeting our energy and environmental challenges is great. ARPA–E can be goal-oriented, flexible, yet possible to start, stop, and sustain programs and projects according to their promise and performance.

Chairman Boehlert, Ranking Member Gordon, and Members of the Committee, thank you for the opportunity to National Academies report *Rising Above the Gathering Storm.* It is a privilege to work together to enable our nation to prosper in the 21st century.

I would be glad to respond to any questions.

BIOGRAPHY FOR STEVEN CHU

Steve Chu, 57, became Berkeley Lab's sixth Director on August 1, 2004. A Nobel Prize-winning scholar and international expert in atomic physics, laser spectroscopy, biophysics and polymer physics, Dr. Chu oversees the oldest and most varied of the Department of Energy's multi-program research laboratories. Berkeley Lab has an annual budget of more than $520 million and a workforce of about 4,000.

His distinguished career in laboratory research began as a postdoctoral fellow in physics at the University of California's Berkeley campus from 1976–78, during which time he also utilized the facilities of Berkeley Lab. His first career appointment was as a member of the technical staff at AT&T Bell Laboratories in Murray Hill, N.J. where, from 1978–87, his achievements with laser spectroscopy and quantum physics became widely recognized. During the last four years there he was Head of the Quantum Electronics Research Department, during which time he began his groundbreaking work in cooling and trapping atoms by using laser light. In 1987, he became a professor in the Physics and Applied Physics Departments at Stanford University, where he continued his laser cooling and trapping work.

This work eventually led to the Nobel Prize in Physics in 1997, an honor he shared with Claude Cohen-Tannoudji of France and United States colleague William D. Phillips. Their discoveries, focusing on the so-called "optical tweezers" laser trap, were instrumental in the study of fundamental phenomena and in measuring important physical quantities with unprecedented precision.

At the time, Dr. Chu was the Theodore and Francis Geballe Professor of Physics and Applied Physics at Stanford University, where he remained for 17 years as highly decorated scientist, teacher and administrator. While at Stanford, he chaired the Physics Department from 1990–93 and from 1999–2001.

He is a member of the National Academy of Sciences, American Philosophical Society, American Academy of Arts and Sciences, Academia Sinica, and Honorary Lifetime member, Optical Society of America. He is also a foreign member of the Chinese Academy of Sciences and the Korean Academy of Sciences and Technology.

Dr. Chu has won dozens of awards in addition to the Nobel Prize, including the Science for Art Prize, Herbert Broida Prize for Spectroscopy, Richtmeyer Memorial Prize Lecturer, King Faisal International Prize for Science, Arthur Schawlow Prize for Laser Science, and William Meggers Award for Laser Spectroscopy. He was a Humboldt Senior Scientist and a Guggenheim Fellow and has received six honorary degrees.

Born in St. Louis and raised in New York, Dr. Chu earned an A.B. in mathematics and a B.S. in physics at the University of Rochester, and a Ph.D. in physics at UC–Berkeley. He maintains a vigorous research program and directly supervises a team of graduate students and postdoctoral fellows. He is author or co-author of more than 160 articles and professional papers, and over two dozen former members of his group are now professors at leading research universities around the world.

Chairman BOEHLERT. Thank you, Dr. Chu.
Dr. Mowery.

STATEMENT OF DR. DAVID C. MOWERY, WILLIAM A. & BETTY H. HASLER, PROFESSOR OF NEW ENTERPRISE DEVELOPMENT, HAAS SCHOOL OF BUSINESS, UNIVERSITY OF CALIFORNIA AT BERKELEY

Dr. MOWERY. Mr. Chairman, Mr. Gordon, Members of the Committee, I appreciate the opportunity to appear and discuss proposals for the Energy ARPA that have been embodied in legislation—legislative proposals and in the Augustine Committee report.

I confess to some skepticism about the ARPA–E model, as it applies to energy R&D, while at the same time, I share many of the goals embodied in the Augustine Committee report. It seems to me, the biggest question concerning the proposal for an Energy ARPA really is the—concerns the problem within the energy R&D system that this entity is—seeks to solve. I share the concerns expressed by the NAS panel and other expert groups over the disparate growth in federal funding for biomedical and physical sciences R&D during the past two decades, and I think a strong case could be made for increased federal investment in energy efficiency, conservation, and alternative energy programs in the face of essentially flat funding since the early 21st century. But many of these concerns, if not all of them, can be—in my view, can be addressed through mechanisms other than the establishment of a new entity within DOE. And I think the proposal for an Energy ARPA overlooks some critical features of energy R&D, some of which were eluded to by Chairman Boehlert, that make the DARPA model less applicable to the field of energy R&D.

So let me just kick off the areas in which I agree with the panel's recommendations and then spend more of my time on the areas in which I disagree, in hopes of sparking some debate.

I think that the proposals for expanded R&D in energy—in alternative energy R&D are very positive. I served on another National Academy of Sciences panel that assessed the value of DOE investments in alternate energy, energy conservation, and energy efficiency programs, and our consensus was that the returns to these investments was positive. And we felt that the Department of Energy had, overall, done an effective job of managing these.

I think, also, that the spirit of the Augustine Committee's recommendations for energy R&D and, more broadly, for retooling the national investment, particularly the federal investment in R&D, on extramural research with a focus on the physical sciences and engineering is a strong positive. I note, as well, that the expanded funding of research in these areas in higher education, in particular, embodies a very effective technology transfer mechanism, the movement of people to and from the university. And I think that that is an important area for expansion and continued activity.

Let me move to the areas in which I disagree with the utility of the DARPA model for energy.

The first, and I think the most important, is the demand side. I—it seems to me that the area of energy R&D is one in which much of the benefit, if not all of the benefit associated with energy

R&D, is embodied in the adoption of these technologies. The technologies yield benefits only to the extent they are applied broadly within the civilian economy. Moreover, broad application of these new technologies often contributes and accelerates their improvement in use. What we know about the first version of many technologies, in energy and elsewhere, is that they tend to be rather user-unfriendly, they, in many cases, are less reliable, and are certainly oftentimes far more costly. Over time, as users learn to operate, maintain, and improve these technologies in the field and as producers incorporate feedback from users, costs drop and performance improves.

The demand side in the energy R&D field seems, to me, is the big—is a big problem. It is not the only problem, but it certainly is a very large problem precisely because federal policy fails to create the kinds of market signals to both support more widespread adoption by users and federal policy, by failing to create those market signals, also tends to discourage private sector investment in the commercialization of the technologies already developed.

So we have, I think, a serious issue on the demand side. And this is clearly something that DARPA and the Defense Department generally have in their quiver of policy weapons that an ARPA–E really doesn't. And as the Augustine panel's report acknowledges, the absence of a strong procurement lever to support the adoption and lower the costs and improve the performance of technologies in use is, I think, an important failing in energy R&D that an ARPA–E cannot overcome.

A second area in which I think the ARPA–E proposal is, perhaps, a bit unrealistic is, and here I am going to opine a bit on politics to a group of experts, but nevertheless, the political environment for energy R&D is clearly much different from the environment within which DARPA achieved a great deal of success in at least two respects. DARPA had a clearly identified client and mission, the uniformed services and the mission on which there was fairly broad political consensus of improving and sustaining U.S. national security. That is not to say that politics did not enter. That is not to say that clashes within the Defense Department over DARPA programs did not exist. Nevertheless, there was a very clearly defined mission and a very clearly defined client, if you will, for the research.

I think this really is lacking on the energy side, making energy R&D far more complex. We have many more user groups with often clashing interests, as is well known, certainly, to this panel and to other witnesses. And we also have a more unstable political environment. Both the economic environment, the price of energy fluctuates over time, and the priorities, the political priorities and goals of energy R&D programs shift over time. That further destabilizes, if you will, the environment within which users adopt and prospective investors commit funds to commercialization.

So let me wrap up here.

First, I want to express my appreciation, and I think we all owe a great debt to the National Academy panel, to its members and its staff, for putting together a very ambitious report that synthesizes a great deal of information and makes a number of important recommendations. And while I don't agree with all of the rec-

ommendations in their totality, I think the contribution of this panel's report to sparking and catalyzing a debate over issues that, for too long, have been frozen in the political debate is extremely important. And I think we are all indebted to them for that.

So thank you, Mr. Chairman, Mr. Gordon, and I am happy to answer your questions.

[The prepared statement of Dr. Mowery follows:]

PREPARED STATEMENT OF DAVID C. MOWERY

I appreciate the opportunity to appear before the Committee to discuss the legislative proposals for an "ARPA–E" that will support R&D on energy technologies that can reduce U.S. dependence on foreign suppliers of oil, reduce pollution, and reduce emissions of other materials that contribute to global climate change. Overall, I agree with the NAS panel's goals in recommending such a program, although I am skeptical about the usefulness of a "DARPA model" for energy R&D.

The Federal Government (and agencies including but not restricted to DARPA) has a long history of supporting R&D that has contributed to the introduction and deployment of technologies ranging from the 19th-century telegraph to civilian aircraft, hybrid corn, and the Internet. Moreover, federal R&D programs in energy efficiency and fossil energy between 1978 and 2000 produced significant economic, environmental, and other benefits.[1] This long history raises some important questions for the design of an ARPA–E.

The biggest question concerning the proposal for an ARPA–E concerns the problem that this entity seeks to solve. I share the concerns expressed by the NAS panel and other expert groups over the disparate growth in federal funding for biomedical and physical-sciences R&D during the past two decades, and a case can be made for increased federal investment in energy efficiency and conservation programs in the face of flat funding since fiscal 2001. But these concerns can be addressed through mechanisms other than the establishment of a new entity within DOE. And the proposal for an ARPA–E overlooks some critical features of energy R&D that make the "DARPA model" less tenable in this field.

1. Who should perform the R&D funded by ARPA–E?

The NAS panel's report emphasized the importance of "rebalancing" the national R&D "portfolio." A combination of factors (including the end of the Cold War) has produced a significant shift in the federal R&D budget in favor of biomedical research. The trends are well known, but bear repeating: federal funding for life sciences R&D grew by 6.2 percent per year from 1982 to 2003, outstripping annual growth rates in federal funding for engineering R&D (2.2 percent) and physical sciences R&D (one percent). "Life sciences" R&D grew from 41 percent of federal R&D funding in fiscal 1994 to nearly 54 percent by fiscal 2003, and the share of federal R&D spending accounted for by "environmental sciences, physical sciences, mathematics, and engineering" R&D shrank from more than 50 percent to less than 40 percent in the same period.[2] In addition, most observers suggest that the "time horizon" of federal and private-sector investments in physical-sciences and engineering R&D has shrunk. The share of overall Defense Department R&D devoted to "basic" research ("6.1") declined from more than five percent in fiscal 1965 to just over 2.5 percent in fiscal 2003.

A more balanced U.S. R&D portfolio should include greater public funding for R&D in the physical sciences and engineering undertaken by extramural performers, notably industry and higher education. Expanded funding for university R&D in particular could increase the supply of U.S. citizens trained in these fields and attract the "best and brightest" from other nations to conduct research and obtain long-term employment in the United States. Moreover, U.S. research universities transfer knowledge and technology very effectively through the placement of graduates in industrial and academic positions.

Although many components of the DOE laboratory system are closely linked with university education and research, the NAS panel rightly emphasizes the importance of extramural R&D performers (defined in this case as entities other than the DOE labs) in its description of ARPA–E. In fiscal 2003, only nine percent of DOE's

[1] See *Energy Research at DOE: Was It Worth It?,* National Research Council Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy (National Academy Press, 2001).

[2] See also *Engineering Research and America's Future: Meeting the Challenges of a Global Economy* (National Academies Press, 2005).

total R&D budget (including defense programs) went to research universities, while 16 percent was allocated to industry. Implementing new programs that follow the spirit of the recommendations in the NAS panel report requires an increase in the share of the DOE R&D budget that is allocated to extramural R&D performers.

It is not clear, however, that an ARPA–E is necessary to achieve this goal. For example, DOE might award grants on a peer-reviewed basis to university research teams that commit to using DOE laboratory facilities, incorporating competition among DOE laboratories to attract high-potential academic research teams. Alternatively (and following the example of DARPA in information technology), DOE could commit to multi-year support for "Centers of Excellence" in interdisciplinary energy R&D at universities through a competitive process. Yet another model for expanding financial support for academic research in the physical sciences and engineering is the Engineering Research Centers established at many universities by the National Science Foundation.

2. What types of R&D will ARPA–E focus on?

The NAS panel report's description of the ARPA–E research agenda suggests that this entity will support R&D on "generic" technologies that are slightly "downstream" from basic research, yet are sufficiently long-term and risky that private industry will not fund them. DARPA's research agenda included both long-term and more applied work, but more discussion is needed on exactly what "gap" the ARPA–E research agenda will fill. As I note below, one of the most significant obstacles to the translation of fundamental research advances into energy-conserving applications is the lack of incentives for users to adopt such technologies.

Another question for an ARPA–E concerns funding levels. Where does the proposed first-year funding of $300 million for ARPA–E fit into the President's requested increase of $391 million for non-defense DOE R&D in fiscal 2007?[3] Would the $300 million in first-year funding for ARPA–E consist entirely of "new money" in addition to the $391 million in increases for R&D requested in the FY 2007 budget document, or would this new entity be funded from a reallocation within the DOE R&D budget? Since one goal of an ARPA–E appears to be a substantial net increase in DOE support for extramural research, the answers to these questions are crucial.

3. Is R&D investment a sufficient condition for advancing U.S. energy goals?

Along with other expert groups, the Committee on Prospering in the Global Economy of the 21st Century highlighted the urgency and significance of energy-related challenges faced by the United States. The development of new technologies is an essential step in addressing these challenges. But realizing the benefits of these technologies requires more than their development by public- or private-sector researchers; widespread adoption of these technologies is necessary.

Indeed, more rapid adoption by users of new technologies can accelerate innovation, as users learn to operate, maintain, and improve them (the Internet in the United States is a classic example). And the need for widespread adoption highlights an important issue for ARPA–E that DARPA did not face: the creation of a market for new technologies. Federal programs supporting technological innovation have proven especially effective when funding for R&D was combined (often through different programs or policies) with complementary policies supporting the adoption of the innovations flowing from publicly funded R&D.

The Defense Department has been an important early purchaser of new technologies ranging from semiconductor components to computer hardware since the late 1940s. This "lead purchaser" role had several important effects: (1) the military market generally paid premium prices, enabling new suppliers to quickly achieve profitability; (2) the military market was sufficiently large that suppliers could exploit learning in production to reduce their manufacturing costs and eventually, lower the prices on new technologies sufficiently to make them competitive in civilian markets; and (3) suppliers used military markets to improve the design and ease of use of new products in ways that further enhanced their attractiveness to civilian purchasers. The procurement budget of the Defense Department aided in the translation of DARPA-supported military innovations into technologies that penetrated large civilian markets, increasing demand and accelerating improvements in the reliability and price-competitiveness of these technologies.

The translation of DOE-funded innovations (whether funded by an ARPA–E or another entity) into technologies that are deployed extensively within the U.S. econ-

[3] This estimate is taken from the AAAS 2/24/06 R&D funding report for FY 2007 DOE R&D, and includes "facilities" funding in addition to R&D. See *www.aaas.org/spp/rd*; accessed March 7, 2006.

omy will require cost reduction and quality improvement of these innovations. Moreover, this "translation" will rely on investments from private firms and entrepreneurs seeking to profit from the commercialization of these technologies. DOE-supported R&D therefore should be complemented by policies that support end-user demand for these new technologies. Examples of such policies include mileage standards for automobiles and energy-efficiency requirements for other technologies; taxes on the carbon content of energy sources; and other mechanisms that create market signals to guide and create incentives for the long-term investment decisions of entrepreneurs and the purchase decisions of consumers.

Indeed, policies supporting the adoption of existing technologies could produce significant near-term improvements in U.S. energy efficiency and, potentially, reductions in pollutants. Wider adoption of these technologies would contribute to more rapid incremental improvements in their reliability and cost-effectiveness. And the cumulative effect of such incremental improvements can be very large indeed.

4. ARPA–E faces a very different political environment than DARPA

Another contrast with ARPA–E is DARPA's single customer and clear mission. Although its relationship with the uniformed services has not been free of conflict, DARPA enjoyed relatively close links with a clear primary "customer." In addition, of course, the broad mission of DARPA—enhancing U.S. military capabilities—was widely accepted across the political spectrum. By comparison, the energy policy arena in which an ARPA–E would be a central actor is characterized by a higher level of political conflict over ends and means, as well as a large number of user constituencies whose needs and priorities may be mutually inconsistent.

Investment in the commercialization of new technologies takes substantial funds and substantial time. Private-sector investment will respond to market-based incentives created by federal policy only to the extent that these federal policies are perceived to be credible, i.e., lasting and reasonably stable. Partly because of wide swings in energy prices and partly because of a lack of political consensus on ends and means, U.S. energy policy has experienced frequent change in goals, political saliency, and program content. Policy instability has raised the risks of investments by private firms in commercializing alternative energy technologies, and almost certainly has reduced the flow of capital into R&D and commercialization in these fields. Although one cannot describe U.S. defense R&D policy as "nonpolitical," the fact remains that the higher level of political consensus on external threats and responses to them since the 1950s has meant that DARPA has operated in a more stable policy environment that enhanced the credibility of its policies and meant that public investments effectively complemented private-sector funding.

It seems likely that the political conflicts that characterize U.S. energy policy will remain significant and that the instability in policy will persist. Such policy instability compounds the technological risks faced by an ARPA–E and will complicate the development of complementary policies to support the adoption of energy-efficient technologies.

Conclusion

I support the broad goals of the Committee on Prospering in the Global Economy of the 21st Century in recommending an ARPA–E. I believe that expanded federal investment in long-term R&D that supports the training of tomorrow's scientists and engineers is needed, and I share the Committee's view that the energy field is one in which the public interest would be well served by greater investment in new technologies. I also believe that the track record of federal R&D investments in the energy field, like many other fields of technology, is a mixed but on the whole positive one. But I am not convinced by the Committee's arguments that a new entity within the Department of Energy is the best means for achieving these goals.

On balance, I believe that a stronger case for an ARPA–E should be based on a clearer analysis of the deficiencies in the current energy R&D structure that includes more detail on how an ARPA–E will address these problems. And as I noted above, there are very important differences between DARPA and the proposed ARPA–E (some of which reflect the differences in their missions) that seem likely to impede the effectiveness of an ARPA–E.

The members (and staff) of the NAS panel should be congratulated for producing an important report (and doing so very quickly) that contains numerous policy recommendations in addition to that for an ARPA–E that merit serious consideration by Members of Congress. It is especially important for members of the Science Committee to attend to the NAS panel's overall analysis of the health of the U.S. innovation system. Actions that reduce federal support for basic research, such as potential cutbacks in NASA space science programs, or policies that may reduce access to higher education, such as cutbacks in federal support for student higher-education

loans, do not advance the goals of *Rising Above the Gathering Storm.* All decisions concerning the allocation of public resources are difficult, and the current (and prospective) environment of revenues and spending pressures has created unusually severe challenges. But federal investments in the future are essential to maintaining the living standards and global leadership that this nation has enjoyed for much of the past century, and a consistent commitment to funding these investments in the future is no less essential.

BIOGRAPHY FOR DAVID C. MOWERY

Education

BA, economics, Stanford University

MA, economics, Stanford University

Ph.D., economics, Stanford University

Positions Held

At Haas since 1988

1988–present—Professor, Haas School of Business, UC–Berkeley

1988–present—Director, Ph.D. Program, Haas School of Business, UC–Berkeley

1988–present—Deputy Director, Institute for Management, Innovation, and Organization

1988—Research Associate, National Bureau of Economic Research

1982–88—Assistant and Associate Professor, Social and Decision Sciences Department, Carnegie-Mellon University

1987–88—Assistant to the Counselor, Office of the United States Trade Representative

1987–88—Fellow, Council on Foreign Relations International Affairs Fellow

1986–87—Study Director, Panel on Technology and Employment of the National Academy of Sciences

1984–86—Visiting scholar, Center for Economic Policy Research, Stanford University

1981–82—Post-doctoral Fellow, Harvard Business School.

External Service and Assignments

- Expert Witness, Congressional hearings on science and technology policy issues
- Member, National Research Council panels, including Competitive Status of the U.S. Civil Aviation Industry, Causes and Consequences of the Internationalization of U.S. Manufacturing, Federal Role in Civilian Technology Development, U.S. Strategies for the Children's Vaccine Initiative, and Applications of Biotechnology to Contraceptive Research and Development
- Member, Committee on Science, Engineering, and Public Policy, American Association for the Advancement of Science, 1997–2003; Member, Presidential Commissions on Offsets in International Trade, 2000–2001
- Co-Editor, *Industrial and Corporate Change,* "Special Issue in Honor of Richard Nelson," 2001
- Co-Editor, *Management Science,* "Special Issue on University Technology Transfer and Entrepreneurship," 2001
- Adviser, Organization for Economic Cooperation and Development and various federal agencies and industrial firms.

Current Research and Interests

- Impact of technological change on economic growth and employment
- Management of technological change
- International trade policy and U.S. technology policy, especially high-technology joint ventures.

Selected Papers and Publications

- "The Sources of Industrial Leadership: Introduction," (with R.R. Nelson), in D.C. Mowery and R.R. Nelson, eds., *The Sources of Industrial Leadership* (Cambridge University Press, 1999).
- "The Global Computer Software Industry," in D.C. Mowery and R.R. Nelson, eds., *The Sources of Industrial Leadership* (Cambridge University Press, 1999).
- "The Evolution of Strategy in the World's Largest Chemical Firms," (A.D. Chandler, T. Hikino, and D.C. Mowery), in A. Arora, R. Landau, and N. Rosenberg, eds., *Strategy for Competitiveness: The Global Chemicals Industry* (John Wiley & Sons, 1998).
- "Collaborative R&D: How Effective Is It?" *Issues in Science and Technology,* 1998.
- *Paths of Innovation: Technological Change in 20th-Century America,* (with N. Rosenberg). Cambridge, MA: Cambridge Univ. Press, 1998.
- Editor. *The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure.* Oxford, England: Oxford University Press, 1996.
- *Science and Technology Policy in Interdependent Economies.* Norwell, MA: Kluwer Academic Publishers, 1994.

Teaching

- BA 292B–1, Behavioral Science, Fall 1998

Honors and Awards

- Earl F. Cheit Award for Excellence in Teaching (Ph.D. Program), 1996, 2001
- Raymond Vernon Prize, *Journal of Policy Analysis and Management,* 1992
- Co-author of paper named a "Significant Article," 20th Anniversary issue of *Research Policy,* 1993
- Fritz Redlich Prize, Economic History Association, 1987
- Newcomen prize, *Business History Review,* 1984
- A.B. with Honors and Distinction; Phi Beta Kappa, 1974

Chairman BOEHLERT. Thank you so much, Dr. Mowery.
Ms. Kenderdine.

STATEMENT OF MS. MELANIE KENDERDINE, VICE PRESIDENT, WASHINGTON OPERATIONS, GAS TECHNOLOGY INSTITUTE

Ms. KENDERDINE. Chairman Boehlert, Mr. Gordon, Members of the Committee, thank you for the opportunity to testify this morning.

Listening to all the Members' opening statements and being the third witness, as opposed to the first, makes me want to do what I shouldn't do, but I will anyway, which is deviate from my prepared text.

The—I was also the Director of the Office of Policy at the Department of Energy. I worked at the Department of Energy for all eight years of the Clinton Administration. My portfolio also included being the Senior Policy Advisor to the Secretary on Oil, Gas, and Coal. I am the only person here without a "Dr." in front of my name. I have a lot of practical experience at DOE, and I approach this from a policy perspective. And after I left the government, I continue to work in both formal and informal energy policy groups, and we always get down to debating. Nobody debates the need to get off oil. That is kind of a fundamental point of agreement, and I do oil and gas, so it is a little bit dangerous to say that. But no one ever really debates that in the groups that I work with.

But we always—our discussions always fall apart when we get to the point of determining how we get off oil. And I would agree with Dr. Mowery. It is a very, very complicated problem. But I also think that it is a very urgent problem. And I would make—starting out, looking at my testimony, writing my testimony, trying to figure out what the real market failure is, on oil. And what are we trying to address? What market failure are we seeking to address? And I would take that to its highest level.

I have spent a lot of time in OPEC countries when I was at the Department of Energy. And we do have a cartel. And when I watch what happens to prices in the market and see what the cycle has been on oil prices, what I can say to you is the OPEC Saudi Arabia dream market is four years of the extremely high prices, which we are in that cycle now, and then one year of extremely low prices. Because what that does is disincentivizes the private sector and the public sector from investing in the research that we need to get off oil.

And so I think my first point is that it is a fundamental, long-term commitment that we need to be making. It is expensive, and it is complicated.

And as such, now I go back to the prepared text.

The ARPA–E proposal constitutes a welcome effort to respond to critical energy needs by accelerating research in game-changing technologies. I think, given the attributes of DARPA, it makes sense for ARPA–E as a starting point. There are, however, fundamental differences between the DOD and DOE cultures and customers that would have to be addressed for an ARPA–E to succeed. And as Chairman Boehlert and Congresswoman Biggert and others have pointed out, the difference in the customer base for DARPA. The customer base is the military. It has a lot of researchers out in the community. Those are performers; they are not customers. And, as other panelists have noted, DOE customers are the industry that—the private sector measures the value of R&D in terms of the price of a commodity. The technology winners from DOE research could strand energy assets in investments. And consequently, there is a huge aversion to picking winners in the DOE culture and applied energy R&D programs.

I also think there will be a temptation to fund an ARPA–E from existing programs, most likely at lower than recommended levels. There are two risks to this approach. First, it would likely intensify internal DOE program resistance to ARPA–E and could jeopardize its establishment. And second, inadequate funding levels could set the program up for failure and confirm the prognostications of the skeptics, some of whom are at the table today.

The following are some thoughts about how to make ARPA–E actually work at the Department of Energy in practice.

To a large extent, the policy focus of ARPA–E, as I understand it, having read the report, is energy sustainability, and that duplicates the mission of a lot of the existing programs at DOE. There are, however, some inherent gaps in the DOE structure that I think an ARPA–E could address.

First, DOE's applied research programs are organized around fuel sources: coal, oil, gas, nuclear, and renewables. This structure runs the risk of—for—and I saw this many times at DOE, runs the

risk of, for example, isolating oil supply research from transportation research, when we are developing engines in one program at the Department of Energy and we don't have fuels to run them on from the other part of the Department of Energy that is responsible for doing that.

Our fossil fuel program at DOE is completely separated culturally and bureaucratically from the efficiency programs when 86 percent of our energy consumption is fossil fuels. Efficiency and fossil fuel programs should be connected much more so than they are in the current structure at DOE. I think this promotes a tendency to focus on incremental or discreet technologies as opposed to systems.

Second, the organizational separation of DOE's basic and applied energy research programs, and that is organization separation, makes the migration of basic research findings to applied research solutions undisciplined, difficult, and often serendipitous.

To some extent, an ARPA–E would provide a formal integrating function that fosters a portfolio or a systems approach to an energy problem. Also, replicating DARPA's formal extraction of value from the entire research continuum from basic to applied to demonstration would be unique to the DOE's system. There are exceptions to that. Those are usually within programs, not across programs.

There is, however, a danger in this kind of structural distinction of ARPA–E from the DOE programs, as opposed to policy-driven distinctions. ARPA–E could risk becoming an organization in search of a mission if there is not a lot of discussion and articulation of a clear mission by the policy-makers in charge.

ARPA–E could accommodate the DOE's customer-based differences by aggregating, through projects and advisory groups, and DARPA does a lot of that as well: one, technology investors who fund research at all stages of all technology development; two, technology developers who conduct basic and applied research, the entrepreneurs who provide ideas and expertise to technology deployers; and technology deployers who are the purchasers and users of advanced technologies. This would also maximize opportunities for successful technology transfer.

Consortia provide another avenue for accommodating DOE's unique base—customer base as well as mitigating concerns about winners—picking winners. An example of this approach is seen in the natural gas supply R&D program included in EPACT last year. Like ARPA–E, this program provides an additional research management tool for DOE, requiring that the program be managed by a competitively-selected consortium that includes representatives of all sectors of the gas supply value chain.

Finally, if Congress decides to establish ARPA–E, it should provide new money at full funding, either through appropriations or through alternative energy—or through alternative funding sources. I appreciate the tight budget constraints. I was distressed at the debate for the energy bill a couple years ago when—the one that failed by filibuster that the argument was over—we were going to—that the $30 billion price tag over 10 years. I thought that $3 billion a year for our energy future was not a lot of money to spend. I think that the—we are in perilous energy times. Just

as we need new innovative programs to address critical energy imperatives, we also need innovation in how to pay for them.

The Natural Gas Supply Research Program described earlier is funded through a trust fund at Treasury, and it receives mandatory funding from the federal oil and gas royalties. Given the fundamental role energy plays in our national and economic security, perhaps it is time to put energy on par with highways and historic preservation, both of which have statutorily-directed trust funds.

Thank you. I look forward to your questions.

[The prepared statement of Ms. Kenderdine follows:]

PREPARED STATEMENT OF MELANIE KENDERDINE

Chairman Boehlert, Mr. Gordon, thank you for the opportunity to testify before your committee this morning.

Mr. Chairman, rising energy demand, constrained supplies, high and volatile energy prices, the geopolitical entanglements associated with the concentration of energy resources, and suggestions of sooner-than-anticipated impacts of global climate change, test the resilience of our economy and our scientific and engineering preparedness. They also test our policy choices, including the investment of scarce federal research dollars.

These and other pressing energy issues suggest that we have a relatively short time frame to initiate fundamental changes in how we produce, distribute and consume energy. Not only do we need to develop new technologies to provide sustainable energy supplies but the lead times for infrastructure investment and construction and capital stock turnover are daunting.

One of the most significant challenges facing energy policy-makers is how to calibrate our energy policy responses and investments to overcome these time constraints, and to do so in ways that minimize price volatility, environmental impacts, global geopolitical tensions, and the stranding of industry assets.

The "ARPA–E" proposal constitutes a welcome effort to respond to these and other critical energy needs by accelerating research in game-changing technologies. I applaud the National Academy for its success in bringing this issue into focus in its recent report *"Rising Above the Gathering Storm,"* Congressman Gordon for introducing legislation in support of ARPA–E, and Chairman Boehlert and the Committee for this hearing today which provides us with an opportunity to discuss how an ARPA–E and its possible refinements might advance key energy policy objectives.

DOE's programs, researchers and laboratories conduct high quality and important work on behalf of the Nation. DOE's applied research programs were deemed fundamentally "worth it" in a previous and relatively recent National Research Council report. Implicit in the NAS Committee recommendation for an ARPA–E, however, is the need for a new way to conduct a portion of the Nation's energy research business at the Department of Energy. This should not be read as an indictment of DOE's energy research programs. Rather it represents an attempt to effectively address serious and gathering energy needs in a compressed time frame—an additional tool for accelerating the transformation of the energy marketplace.

Before a discussion of some general concerns with the specifics of ARPA–E, it is instructive to review some of the desirable features of DARPA that are highlighted in the NAS report (presumably for replication):

- A small, relatively non-hierarchical organization
- Flexible hiring and contracting practices that are atypical of the Federal Government
- The ability to hire quickly from the academic world and industry at wages substantially higher than those of the federal workforce
- Short tenures, turnover of personnel enabling fresh leadership and ideas on a continuous basis.

It is noteworthy that these attributes focus primarily on *process*—relative freedom from the restrictions and requirements under which most federal research programs operate including burdensome contracting, reporting, and oversight orders and regulations, low pay grades, the rigidities of the civil service system, and multi-leveled management hierarchies.

Other *structural or research model* features of a DARPA that are highlighted as desirable for translation into an ARPA–E include:

- A lean, effective, agile—and largely independent—organization that can stop and start targeted programs based on performance and. . .relevance
- Creative, out of the box transformational research that could lead to new ways of fueling the Nation. . .as opposed to incremental research on ideas that have already been developed
- Longer-term research funding in a highly flexible program—risk taking.

While not specifically highlighted in the NAS report, some additional desirable features of DARPA (included in presentations by Dr. Richard Van Atta, formerly with DARPA) are:

- Development of integrated concepts beyond the purview of a single service
- Taking on large-scale proof of concept demos with a scientific process and a willingness to fail
- Working with the OSD leadership to broker the commitment of the services.

Given these attributes and features, the NAS recommendation of the DARPA model as a starting point makes sense. There are however some fundamental differences between the DOD and DOE cultures, bureaucracies and customers that necessitate significant calibration of the DARPA model for an ARPA–E like program to be successful at DOE. We have been asked to respond to a set of questions about the ARPA–E approach. I will briefly discuss certain issues raised by ARPA–E as proposed by NAS then address the questions you have asked me by offering some thoughts on possible refinements of the ARPA–E concept.

General concerns with ARPA–E as described in the NAS report fall into the following areas:

- Program objectives
- Organization/reporting
- Customer base
- Funding/matching funds.

Objectives of ARPA–E. It is unclear from the NAS report precisely what type of research outcomes and objectives the Academy contemplates for an ARPA–E. The report indicates that ARPA–E should fund and manage "transformational" and high-risk, high-payoff research, which is defined earlier in the report as a "subset of basic research." The report, in discussing the need for ARPA–E says that, "In particular, ARPA–E could invest in a broad portfolio of foundational research. . .." This objective is not easy to distinguish from that of DOE's Office of Science; this office is already funded at around $3.6 billion per year and has received a half-billion dollar plus-up in the President's FY07 budget request.

The NAS report also describes ARPA–E's benefits to include "[accelerating] innovation in energy and the environment for both traditional and alternative energy sources and in energy efficiency mechanisms." Further, the report's description of ARPA–E identifies very specific research structures and technologies, indicating that one of ARPA–E's benefits would be "[fostering] consortia of industry, academe, and laboratories to work on critical research problems, such as the development of fuel cells." These program benefits and targets suggest an applied research program and appear to conflict with the definition of basic research which eschews timeframes, specific applications and products and focuses instead on "gaining knowledge or understanding of the fundamental aspects of phenomena."

These descriptions beg several questions. Is ARPA–E primarily a basic research program, an applied research program, a program to "turn cutting edge science and engineering into technology," an effort to accelerate commercialization, or all of the above? Each of these suggests different leadership, organizational structures, personnel capabilities, and reporting chains, as does a single program that contemplates performing *all* these functions (an approximation of DARPA). A clarification of program objectives will drive the research management model and is fundamental to program success. Further, there needs to be a clear delineation between DOE's existing basic and/or applied research programs and ARPA–E's mission, research targets, reporting chain, etc.

ARPA–E Organization/Reporting. The NAS recommends that the ARPA–E program director report to the Under Secretary of Science. The ARPA–E proposal represents a fairly significant departure from how DOE currently conducts business. It is bound to raise issues of coordination with existing programs, concerns about picking winners, and other potential oversight issues as the program breaks new and controversial ground.

These are sensitive issues both internally and externally and may require the imprimatur of the Secretary or Deputy Secretary whose portfolios are the broadest and authorities are sufficient to manage and mediate the controversies that could arise from such a fundamental change in approach to DOE research management. Also, the unique contractual, personnel and pay scales contemplated in an ARPA–E program may require greater organizational separation from existing programs (organizational independence is identified as a key positive feature of DARPA) than is possible in a reporting structure through the Under Secretary with line authority for other programs.

ARPA–E Customer Base. The nature of the customer base serves as a key point of departure from a pure ARPA–E replication of DARPA and what might actually work at DOE; this difference is not trivial and should inform this discussion and its outcomes.

DARPA funds a large network of researchers outside of the Defense Department; these are, however, DARPA-funded "performers" as distinguished from its "customers." DARPA's sole customer and the focus of its mission—*"to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use"*—is the military. As such, the peril of "picking winners" by DARPA is very manageable as there is only one customer valuing the results.

This is contrasted with the ultimate customers for the products of DOE's applied energy research programs—literally thousands of players in a single energy sector, multiplied by the many different sectors that comprise our energy industry. Further, most of these customers are private industry stakeholders for whom the value of research is measured in the price and availability of a commodity. This places high value on short-term results. Also, picking winners and losers could affect both the value of that commodity and the relative worth of the research beneficiaries; cost and price are critical measures of success. Finally, picking winners threatens to strand existing industry assets. As such, the peril to bureaucrats, researchers and program funding is significant and much more subject to external political pressures; picking winners, as a matter of DOE policy, is often actively discouraged or resisted.

Funding Mechanism/Cost Share. The NAS report recommends funding levels of $1 billion a year for ARPA–E after an initial ramp-up period, a level deemed necessary for program optimization and success. Needless to say, finding new money at this level will be difficult and there will be a temptation to carve out funds for ARPA–E from existing programs, most likely at levels that are substantially lower than those recommended in the Academy report.

There are two risks to this approach: 1) seeking funds from existing programs will likely intensify internal DOE program resistance to ARPA–E and could jeopardize the establishment of the program, and; 2) an ARPA–E program, by virtue of its new and unique approach to research management at DOE, will be controversial. Inadequate funding levels, through either appropriations or a re-programming of funds from existing programs, could help ensure program failure, confirming the prognostications of program skeptics.

It is worth noting that at DOE an ARPA–E that is focused primarily on applied R&D (or includes a substantial applied R&D component) would typically require industry cost share (which is not the case at DARPA). Federal procurement, intellectual property, contract management provisions, DOE orders and other federal requirements are off-putting to many industry players, placing de facto barriers to industry participation and cost share commitments—essential elements to successful applied energy R&D, including demonstration, deployment and technology transfer.

Federal energy R&D is performed under the constraints of annual appropriations which are inconsistent from year-to-year, administration-to-administration and secretary-to-secretary. Also, program funds are largely "mortgaged" from the start, and increasingly line-itemed. The risks and limitations of the funding process further discourages industry participation and its commitment of matching funds, making it more difficult to optimize the migration of technologies into the marketplace. If ARPA–E is funded at relatively low levels in its early years, the ramp-up in the out years as contemplated in the NAS report would place that important increment (likely necessary when projects get to the demonstration phase, for example) in competition with other DOE programs as well as with programs in other agencies that are funded through the Energy and Water Appropriations Committee; this lack of certainty in out-year funding could further complicate and discourage longer-term industry commitments to critical projects.

Making ARPA–E Work. The following are some thoughts and recommendations (strictly my own, there are many alternatives and options) on how an ARPA–E might accommodate some of the idiosyncrasies of the DOE culture, structure and customer base that could maximize program effectiveness and address some of the concerns articulated in the Committee's questions.

Role of ARPA–E at DOE. There are many high level policy objectives that could serve as the basis for ARPA–E research investments, given the broad range of energy needs facing the Nation. I would recommend four areas that could provide focus as well as an organizing function, although ARPA–E program managers should be given wide latitude in addressing these challenges including the freedom to deviate from core focus areas if warranted. Also, these focus areas do not approximate the "strategic thrusts" of DARPA, which for a new ARPA–E would have to be identified after significant analysis and discussion. General focus areas for ARPA–E, however, should include:

- development of economically sustainable energy sources, which implies a reduction in oil consumption and U.S. reliance on imported energy from unstable regions of the world, and the development of domestic, hemispheric and alternative energy sources
- environmental mitigation, particularly greenhouse gas capture and sequestration,
- energy infrastructure development to produce, refine and distribute new sources of energy
- energy efficiency, with a focus on end use efficiencies.

To a large extent, these focus areas duplicate those of existing DOE programs, which have developed numerous high-impact technologies, and have enhanced the Nation's knowledge base in critical areas. There are however, some gaps inherent in the structure of DOE programs:

- DOE's applied research programs are organized around fuel sources, e.g., coal, oil, gas, nuclear, renewables (the efficiency program is an exception). The existing organizational structure and focus provides a solid foundation for the Department's applied research and the support of strong constituencies; it runs the risk however of isolating oil supply from transportation or fossil fuels from efficiency, for example, and promotes a tendency to focus on incremental or discrete technologies (exceptions are generally *within* programs, not *across* programs) as opposed to systems that integrate research needs from supply to distribution to end use.
- The organizational separation of DOE's basic energy research program from its applied research programs makes sense in many instances, but it also makes the migration of certain basic research *findings* to applied research *solutions* undisciplined, more difficult, and often, serendipitous.

There are both ad hoc and, in some instances, formal structures at DOE that encourage communication and coordination between the various applied research programs and between the applied research and basic research programs. In the final analysis, however, the competition for funding from the same appropriation, bureaucratic separation, and different program cultures and performance measures, ultimately work against optimum levels of cooperation and coordination across programs.

An ARPA–E like program could help fill these gaps and supplement but not supplant the missions of existing DOE programs. As noted earlier, the "development of integrated concepts beyond the purview of single service [program]," is one of the features of DARPA that is desirable for replication. To some extent, on certain key problems to be identified, an ARPA–E could provide the *formal integrating function* that fosters a portfolio approach to a problem. In addition, providing ARPA–E with *administrative flexibility* in contracting, hiring, etc., and the easy transfer of personnel and ideas between the government, industry and academia will further distinguish ARPA–E from existing DOE programs.

Finally, replicating DARPA's formal *extraction of value from the entire research continuum*—from basic to applied to development to deployment—would be largely unique to the DOE system (DARPA's budget reflects the research continuum including basic and applied to large scale demonstration). Directing a minimum percentage of program funds to basic research—for both the national laboratories and universities—would protect against the tendency of DOE's energy R&D customer base comprised largely of industry to focus on near-term research and results. Congress might also consider setting aside a portion of ARPA's funds as venture capital for promising, innovative opportunities in the private sector.

In short, ARPA–E would be distinguished from existing DOE programs more by its structure than by the policy objectives its research would address. There is, however, a danger in a "structural" as opposed to policy-driver distinction; without an upfront, clear articulation of some fundamental strategic research thrusts, an ARPA–E could risk becoming an organization in search of a mission. Nevertheless, the drivers described above do not differ substantially from similar gaps DARPA seeks to fill—"research that the services are unlikely to support because it is risky, does not fit [the services] specific roles or missions, or challenges their existing systems or operational concepts."

ARPA–E Reporting Structure. From an organizational/reporting perspective, it is essential to program success that the ARPA–E program director be a direct report to either the Secretary or Deputy Secretary for the reasons articulated earlier in this discussion. This would be especially important in the start-up years of the program to help maximize opportunities for success and tracks the development of DARPA, which also reported to the Secretary and Deputy Secretary in its early years.

The size and nature of the program also raises the issue of whether or not the program director should be Senate-confirmed. ARPA–E would be both controversial and engaged in high-risk, high-payoff research, which suggests, at times, high-profile failures. Also, depending on the final shape of ARPA–E, the program director will require a very unique skills set, likely to include a combination of research, government and industry experience. Selection of the best individual as program director is critical, as is continuity in that position. This should not be considered a political job; insulating the director's position from the confirmation and/or political appointment process is desirable, as would be assistance in the search for the right individual with the right credentials from, for example, a subcommittee of the Secretary of Energy's Advisory Board (SEAB).

DOE Customer Base. Accommodating the differences between the DARPA and DOE customer bases is one of the biggest challenges for an effective ARPA–E. Ideally, an ARPA–E would aggregate these key players in the research value chain: (1) technology investors who fund research at all stages of technology development; (2) technology developers who conduct basic and applied research; (3) entrepreneurs who provide ideas and expertise to technology deployers; and (4) technology deployers who are the purchasers of technology and use advanced technologies for energy production, distribution and end use. A formal advisory committee structure that includes representatives from each of these stakeholder groups could provide important strategic direction and real-world input, but care would need to be taken to ensure that this does not limit the flexibility of program managers. Accommodating the views and interests of these key players in the research value chain would also maximize opportunities for successful technology transfer and diffusion in the energy marketplace.

Research management and research performing consortia provide additional avenues for accommodating the interests of diverse and numerous industry customers as well as for mitigating concerns about picking winners. An example of this approach is seen in the Ultra-deepwater and Unconventional Natural Gas Supply R&D program included in EPACT last year. Like ARPA–E, this program provides an additional tool for managing DOE research. While directing substantial oversight by the Department, including strict conflict of interest provisions, it requires that the program be managed by a competitively selected research management consortium that includes industry, academia, national laboratories, venture capital firms, service companies, private research institutions and large end users representing all sectors on the gas supply value chain. The consortium is not a research *performer;* rather, with the approval of DOE, it establishes the research agenda, develops project specifications, selects and manages research projects, and transfers the technology into the marketplace. The program also includes a complementary research program element at the National Energy Technology Laboratory.

Funding ARPA–E. If ARPA–E is designed to fill the gaps in the current DOE structure as an agile "integrator" that extracts value from the entire research value chain—as well as a high-risk, high-payoff and long-term research manager—it needs to be insulated from external pressures and the natural resistance of existing DOE programs to the maximum extent practicable. In this regard two things are worth noting: the NAS report indicates that in the beginning DARPA was "threatening" to the DOD research establishment; and high risk research projects are bound to have a relatively high failure rate. As such, at a minimum, ARPA–E should be a Congressionally-endorsed program funded with new money, at the full one billion dollar level. It should, however, be given the flexibility of "no year" money in order to ramp up in the early years and accrue funds for the more expensive out years.

Funds for new program are however extremely tight. As such, the Congress should also consider other options to pay for ARPA–E. The Natural Gas Supply Research Program described above is funded through a Trust Fund at Treasury and receives mandatory funding from federal oil and gas royalties. The Energy Information Administration analyzing an earlier version of this program indicated that it would result in increased domestic gas supplies and attributed its probable success to the funding certainty of the Trust Fund. There is an attractive policy synergy in utilizing oil and gas royalties to develop sustainable energy sources; the royalty stream would, however, have to be sufficiently robust over time to help fund this transition.

Another option the Congress might consider is the mechanism used to fund DOE's Clean Coal program, which received it entire multi-year funding in a single year and from which it has been drawing down over time as projects are approved and implemented. This does not address concerns over the funding of new starts. It would however address key issues with respect to maintaining industry support and cost share by demonstrating that the government would be a reliable partner over a long period of time.

Finally, the Congress might consider the results of a recent poll that indicated the American public would support an increase in the gasoline tax *if* the funds generated from the tax were directed to reducing our oil reliance and addressing climate change. To ensure the public that these funds were being wisely spent, the funds would need to be segregated into an innovative and cross-cutting program like an ARPA–E. A one cent per gallon gasoline tax would pay for the entire ARPA–E program at levels recommended in the NAS report.

Mr. Chairman, generating sufficient energy to power the world in ways that protect the environment and promote global economic growth is one of the most significant imperatives of our time. To meet this challenge, we should be prepared to commit significant resources, consider all options, and empower the innovators.

There are significant issues that must be addressed and refinements that would have to be made to make ARPA–E succeed in the DOE culture and bureaucracy. If properly organized, empowered, and funded, however, an ARPA–E type program could provide a new and aggressive link between the needs of the energy marketplace and research directions, operating as a primary interface between the energy industry and DOE's national laboratories and experts in academia.

Thank you for this opportunity and I look forward to the Committee's questions.

BIOGRAPHY FOR MELANIE KENDERDINE

Melanie Kenderdine of Gas Technology Institute (GTI) provides commentary on the natural gas industry and issues related to U.S. energy policy and legislation. With more than two decades of experience in both federal and private energy sectors, she understands and communicates effectively about energy issues and policies, as well as the latest developments in pursuit of natural gas and other energy sources. She is particularly knowledgeable about trends in domestic and world energy supplies and in technologies that will impact energy supply and demand.

Trend: Industry is the single largest consumer of natural gas in the United States. But the high cost of natural gas is driving natural gas dependent industries overseas, despite abundant technically recoverable domestic natural gas reserves. Making these reserves more economic to produce and developing efficiency technologies to enhance natural gas consumption are crucial to the Nation's industrial base, to residential consumers and to its economic security.

Trend: In an age of heightened domestic security, protecting our nation's energy infrastructure is crucial to protecting our economy. With 1.8 million miles of natural gas pipeline connecting the majority of U.S. homes and workplaces, working with industry and government to secure the infrastructure in ways that are easily integrated into industry is critical. GTI is working with industry and the Federal and State governments to ensure that we maintain the security, integrity, safety and reliability of this infrastructure.

Accomplishments:

- Director, Office of Policy, U.S. Department of Energy (DOE)
- Senior Policy Advisor, DOE, oil, gas, coal and nuclear issues
- As Senior Policy Advisor was the Architect for:
  - R&D initiatives for ultra-clean fuels and energy grid reliability
  - Strategic Petroleum Reserve royalty-in-kind initiative

- National Energy Technology Laboratory Strategic Center for Natural Gas Studies
- DOE response to Japan nuclear accident, 1999.

Presentations & Speeches:

- "Issues for Evolving LNG Markets," Montreux Energy Roundtable XV, Montreau, Switzerland, Sept. 27–29, 2004
- "Energy and Nanotechnology: Strategy for the Future," Natural Gas Technologies For The Future, Houston, Texas, May 2–4, 2003
- "The 10/50 Solution," Pew Center on Global Climate Change/NCEP, Washington, D.C., March 24, 2004
- Sixth Annual International Energy Experts Conference, Abu Dhabi
- Congressional Testimony—numerous appearances on energy related issues.

Publications & Interviews:

- Harts E&P, "Offshore Report: Ultradeepwater R&D program needed," September, 2001
- Physics Today, "Meeting Energy Challenges: Technology and Policy," April, 2002.

Education:

B.A., Political Science, University of New Mexico.

Chairman BOEHLERT. Thank you very much.

Dr. Fernandez.

STATEMENT OF DR. FRANK L. FERNANDEZ, PRESIDENT, F.L. FERNANDEZ, INC.

Dr. FERNANDEZ. Mr. Chairman, Members of the Science Committee, I am pleased to have been asked to give you my views on DARPA and the possible utility of a similar organization in the Department of Energy.

Now I am not an expert on energy matters, so my comments are structured to describe the way things work at DARPA actually and to provide suggestions to things that the Committee might want to consider if it does decide to create an ARPA–E.

My experiences with DARPA goes back almost as far as DARPA. I have been working as a contractor for DARPA. I worked as a representative of the Chief of Naval Operations in negotiations with DARPA, and finally as the Director of DARPA from 1998 to 2001.

In my experience, the fundamental reason for the existence of DARPA in the Department of Defense has never really changed since it was created in 1958, a reaction to stove-piped military services' disconnected space programs that led to America's Sputnik failure.

DARPA began as a result of a serious political embarrassment, not as a result of well-meaning panels. The reason—this reason for DARPA, then, is a belief that in order to maintain United States technological superiority into the future over potential adversaries, the Department needs a central organization reporting to the Secretary to create and fund the high-risk, potentially high return R&D projects, and that this activity needs to exist in addition and independent of the military service funded research and development, even if this is perceived to be in competition for important resources.

This belief is based on the very critical observation over the years that in many R&D organizations, and in the DOD in particular, stove pipes always seem to rise and thrive and that they develop risk-averse parochial views, which can seriously misjudge the potential for new high-risk, technologically-enabled opportunities and threats.

The recommendation to create a central agency in the Department of Energy makes sense to me if it turns out that the Department also has this stove pipe problem that exists in the Department of Defense.

DARPA's function, then, is to work across and around these stove pipes for important, national defense problems.

To do this, DARPA utilizes a two-pronged approach.

First, it opportunistically finds and funds long-term, outcome-focused R&D projects, using the best talent in universities, laboratories, and industry, even if it doesn't always get everything right.

In parallel, it demonstrates and tries to make a market for these technologies by helping to fund developments needed for the military and commercial adoption.

I think that this ability to simultaneously fund focused, long-term research and to act as a market-maker with potential customers is a critical difference between DARPA and other DOD research and development entities. DARPA is basically the DOD agent for change.

If the Committee decides that ARPA–E is to be such a central organization, then I think, like DARPA, it should have such a two-pronged approach to its funding investment activities.

Now balancing these often conflicting activities requires an organization with special structure, authorities, and operating style.

DARPA is currently an example of such an organization in the Department of Defense. Like DARPA, I think the ARPA–E should be the central agency, and should have a clear, national purpose for its projects that differentiates it from the laboratories and other energy agencies. It should have visibility and access to the top management of the Department and not be a part of an established R&D bureaucracy.

Like DARPA, I think it should have a mandate to create, demonstrate, and transition high-risk, high-return technologies to maintain the United States' technical superiority in energy.

Like DARPA, I think it should be a funding agency with very little infrastructure, a flat organization, and a small, very competent entrepreneurial technical staff. Budget and program control should rest with the Director and the program managers, and the agency should enforce constant turnover of both programs and staff.

Like DARPA, it should have both the special authorities and the resources needed to exercise these authorities. For example, it doesn't do any good to give an organization special hiring or special contracting authority if it doesn't have the contracting and hiring resources in house to implement those authorities, problems that I think existed with the current HS ARPA when they first started.

Unlike DARPA, however, as has been said several times, ARPA–E would be in the energy business, not the defense business. I don't think that it should be a strict clone of the Defense agency. Instead, I think it should receive the funding, flexibility, and leader-

ship authorities, and most importantly, the time necessary to let it become the change agent for the Department of Energy.

DARPA's evolution, especially during its beginning, was not without a lot, and a lot, of problems, and Congressional support was one of the reasons why DARPA is still here today, long-term Congressional support.

Now the final point, if an ARPA–E is created, I think that a DARPA-like model might make some sense, even if the Department of Energy is not the primary consumer of its technologies. This condition is not always necessary for the creation and transition of revolutionary technology.

Let me give you a couple of examples.

In 1962, DARPA found and funded a support network of early information technology researchers at universities and firms that, over time, built a dominant, non-Defense technological capability in something—in personal computing and something called the Internet.

And though the DOD never represented a major market for this capability, and it never did, okay, it was able to take advantage of it quickly and affordably.

In 1987, SEMATECH was created with private and federal funding. And DARPA managed the federal programs, in partnership with industry. SEMATECH succeeded in reestablishing the United States' dominance in semiconductor manufacturing. And without having to make a market, the Department of Defense profited from a very, very competitive industrial base that it could use without fear of control by a foreign power.

The current revolutionary working concept of network-centric warfare in the military, which has enabled the United States to achieve unparalleled dominance, rests, to a great extent, on commercial IT infrastructure, the use of commercial, off-the-shelf technology, much of which is the result of DARPA investments.

In each of these examples, DARPA technology went first to the commercial sector and then got bought by the military, a transition path which is still being followed at DARPA for some of its newer technologies.

Finally, and with all due respect to the Committee, even though I am extremely proud of my association with DARPA, I think it might be helpful if the Committee considered a different name for this new organization, if it creates it, a name that reflects the uniqueness of the 21st century energy needs of this nation.

Thank you.

[The prepared statement of Dr. Fernandez follows:]

PREPARED STATEMENT OF FRANK L. FERNANDEZ

Mr. Chairman and Members of the U.S. House of Representatives' Science Committee, I am pleased to have been asked to give my views on the pros and cons of creating an ARPA–E organization in the Dept. of Energy. I hope that this brief statement addresses your major questions.

At the outset, I need to tell you that, since I have spent most of my career in the defense R&D business, I am not an expert on energy matters. Nevertheless, I hope that my comments will be helpful to the Committee.

For the past forty years I have worked with DARPA as a research contractor representing both small and large companies, as a Navy consultant, representing the Chief of Naval Operations, as Director of DARPA, from May 1998–January 2001,

and, most recently, as a consultant to the current DARPA Director. This variety of views of DARPA forms the basis for what follows.

In my experience, the fundamental reason for the existence of DARPA in the Department of Defense (DOD) has never really changed since 1958, when President Eisenhower created the Agency in reaction to the stove piped military services' disconnected space programs that led to America's Sputnik failure.

The reason for DARPA is a strong belief, currently held by both the executive and legislative branches of the government, is that, in order to maintain U.S. technological superiority over potential adversaries, the DOD needs a central organization, reporting to the Secretary, to create and fund high risk, potentially high return R&D projects. This is in addition to service funded R&D.

This belief is based on the fact that, regardless of intentions, within the DOD, organizational "stove pipes" develop and these "stove pipes" often have risk-averse, parochial views which can misjudge the potential for new, technologically enabled, opportunities and threats, especially if the technology is high risk.

The idea of a central agency, ARPA–E, may make sense if the DOE shares some of these organizational and management problems with the DOD.

DARPA's function is to work across and around these stove pipes for important, national defense problems.

Achieving this mission for almost fifty years has required that DARPA continuously adapt and to a defense environment that has undergone large change because of changing adversaries and, also, because of technology, much of which was the result of DARPA initiatives.

In order to accomplish its mission, DARPA employs a two pronged approach.

It opportunistically, finds and funds long-term, outcome focused R&D projects using the best talent in universities, laboratories and industry.

In parallel, it demonstrates and "makes a market" for these technologies by helping to fund developments needed for military and commercial adoption.

I think that this ability to, simultaneously, fund focused long-term research and to act as a "market maker" with potential customers is a critical differentiator between DARPA and other DOD R&D entities.

DARPA is not bound by DOD acquisition requirements for technology or systems projects. DARPA often mixes basic research, applied research and advanced technology development in its projects to aid the transition of the understanding to war fighting capability.

It is this freedom to innovate that differentiates DARPA from the other DOD laboratories and funding agencies.

This following list of characteristics that help DARPA operate at both the Institutional and personal innovation organization levels is largely drawn from DARPA's own descriptions of its organizing elements:[1]

Small and flexible: DARPA consists of only 100 to 150 professionals; some have referred to DARPA as "100 geniuses connected by a travel agent."

- *Flat organization:* DARPA avoids military hierarchy, essentially operating at two levels to ensure participation.
- *Autonomy and freedom from bureaucratic impediments:* DARPA operates outside civil service hiring and the limits of government contracting rules, which gives it unusual access to talent, plus speed and flexibility in organizing R&D efforts.
- *Technical staff drawn from world-class scientists and engineers:* DARPA's talent is drawn from industry, universities, and government laboratories and R&D centers, mixing disciplines and theoretical and experimental strengths.
- *Technical staff 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 to assure fresh thinking and perspectives.
- *Project-based, organized around a challenge model:* DARPA organizes a significant part of its portfolio around specific technology challenges. Although its projects typically last 3–5 years, major technological challenges may be addressed over much longer time periods, ensuring patient long-term investment, but only as a series of focused steps.

[1] DARPA, DARPA—Bridging the Gap, Powered by Ideas (Feb. 2005); DARPA, DARPA Over The Years (Oct. 27, 2003)

Necessary supporting personnel (technical, contracting, administrative) are used from other agencies on a temporary basis: This provides DARPA flexibility to get into and out of a technology field area without the problems of sustaining staff.

- *Outstanding Program Managers are the heart of DARPA:* 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 is to recruit highly talented program managers and empower them to be creative.
- *Acceptance of failure*—DARPA, at its best, pursues a high risk model for breakthrough opportunities, and is very tolerant of failure if the payoff from potential success is great enough.
- *Oriented to revolutionary technology breakthroughs*—DARPA historically has focused on radical, not incremental, innovation, emphasizing high-risk investment, moving, as noted, technology advances from fundamental through prototyping, then handing off the production stage to services or commercial sector. DARPA often works on solutions to joint service problems which individual services traditionally are reluctant to pursue.
- *Mix of Collaborators*—DARPA typically has tried to build strong teams and networks of collaborators, bringing in a range of technical expertise and involving technology firms that are often not significant defense contractors with outstanding university researchers. The aim is to ensure strong collaborative "mindshare" on the challenge.

If the Committee decides that ARPA–E is to be such a central organization, then, like DARPA, I think that it should have such a two-pronged approach to its activities.

It must find and fund long-term outcome focused R&D projects using the best talent in universities, laboratories and industry. In parallel, and often in conflict with the first part of the approach, it should convince selected parts of the energy industry that its technologies can radically and positively affect the energy business and that these technologies should be adopted. In addition, in partnership with industry, it should help fund the developments necessary to implement these technologies.

Balancing these, often conflicting, goals requires a special structure and operating style and DARPA is an example of something that works in the DOD.

Like DARPA, I think that ARPA–E should be created as the central energy research and development organization in the DOE and should have a clear, national purpose for its projects that differentiates it from the laboratories and other agencies. It should have visibility and access to the top management of the Department and not be part of an established R&D bureaucracy.

Like DARPA, I think that it should have a mandate to create, demonstrate and transition high risk, high return technologies that can dramatically change the U.S. energy posture in the future.

Like DARPA, I think that it should be funding agency, with very little infrastructure, a flat organization and a small, very competent, entrepreneurial, technical staff. Budget and program control should rest with the Director and the program manager and the agency should enforce constant turnover of both programs and staff.

Like DARPA, I think that it should have both the authorities and the resources needed to implement these authorities. For example, while flexible contracting and hiring authorities are necessary, implementing these authorities requires dedicated, in house, resources.

Unlike DARPA, however, ARPA–E will be in the energy business, not the defense business. Congress should not try to make this agency strictly mimic a defense agency that has and continues to evolve to accommodate a changing defense environment.

Instead, I think that ARPA–E should receive the funding, flexibility, leadership authorities and, most importantly, the time necessary to let it become the change agent for the DOE.

I think that a DARPA like model makes sense even if the DOE is not the customer for the technology because this is not necessary for the transition of revolutionary technology.

The most famous example:[2]

[2] Provided by William Bonvillian, from a draft 02/19/06 "DARPA and the Connected Science Model For Its Innovation—Where Should It Go, Now?"

President Kennedy and Defense Secretary Robert McNamara were deeply frustrated with profound command and control problems during the Cuban Missile Crisis—the inability to obtain and analyze real time data and interact with on-scene military commanders. DARPA brings in Licklider to tackle the problem. It is the rare case of the visionary being placed in the position of vision-enabler. Strongly backed by noted early DARPA Directors Jack Ruina, Charles Herzfeld and George Heilmeir, Licklider finds, selects, funds, organizes and stands up a remarkable support network of early information technology researchers at universities and firms that over time builds personal computing and the Internet.

At the institutional organization level, DARPA and Licklider become a collaborative force among the Defense Department research agencies controlled by the services, using DARPA investments to leverage their participation to solve common problems under connected science and challenge models. DARPA and Licklider also keep their own research bureaucracy to a bare bones minimum, using the service R&D agencies to carry out project management and administrative tasks, so that DARPA's efforts create co-ownership with the service R&D stovepipes. Institutionally, DARPA becomes more of a research supporter and collaborator, not a rival competitor to the DOD research establishment. DARPA provides an institutional example within DOD for a way to create a flexible, cross-agency, cross-discipline model among stove piped U.S. R&D agencies. At the personal level of innovation organization, Licklider creates a remarkable base of information technology talent both within DAPRA and in a collaborative network of great research groups around the country.

Because it sees ongoing progress, DARPA is willing to be patient and look at long-term investments in IT talent and R&D investments in a way that corporations and venture capital firms are not structured to undertake. Licklider's DARPA model is also not a flash in the pan. Internally it is able to institutionalize innovation so that successive generations of talent sustain and keep renewing the IT technology revolution over the long-term. At the personal level of innovation, the great groups Licklider starts, in turn, share key features of the Rad Lab group previously discussed. Licklider's Information Processing Techniques group remains the first and greatest success of the DARPA model. But this success is not unique; DARPA is able to achieve similar accomplishments in a series of other technology areas.

One more key point: DARPA was willing to spawn technology advances not only in the defense sector but in the non-defense economy as well, recognizing that an economy-wide scale, as opposed to a defense sector-only scale, is needed to speed the advance. The Department of Defense (DOD) was able to take advantage of this technology evolution speed up, with its shared, and therefore reduced, development and acquisition costs, which enabled DOD to obtain the tools it needed to solve its initial command and control problem more quickly and less expensively.

The DOD was never as major market for personal computing or the Internet.

Another example:

In 1987, faced with a competitor that threatened to control the semiconductor market, the SEMATECH venture was formed to improve domestic semiconductor manufacturing. The federal dollars for SEMATECH were funneled through DARPA because semiconductor manufacturing was seen as vital to the defense technology base.

The success of the SEMATECH partnership in reestablishing U.S. dominance in semiconductor fabrication was in part due to the fact that DARPA, in partnership with industry, was able to rapidly create and fund focused high risk, high return programs.

More importantly, the DOD profited from an industrial base that it could use without fear of control by a foreign power without having to make a market.

A final example:[3]

When Andy Marshall, DOD's legendary in-house defense theorist, announced that U.S. forces were creating a "Revolution in Military Affairs," this defense transformation was built around many of the IT breakthroughs DARPA initially sponsored. Admirals Bill Owens and Art Cebrowski and others, in turn, translated this IT revolution into a working concept of "network centric warfare" which enabled the U.S. in the past decade to achieve unparalleled dominance in conventional warfare.

In each of these examples, DARPA technology went, first to the commercial sector, then to the military, a transition path still followed at DARPA for many revolutionary technologies.

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[3] Provided by William Bonvillian, from a draft 02/19/06 "DARPA and the Connected Science Model For Its Innovation—Where Should It Go, Now?"

Finally, and with all due respect, even though I am extremely proud of my associations with DARPA, I think that it might be helpful if the Committee considered a different name for this new organization, a name that reflects the uniqueness of the twenty first century energy needs of the Nation.

Thank you.

BIOGRAPHY FOR FRANK L. FERNANDEZ

Dr. Fernandez' experience and knowledge encompasses a very broad range of research and management areas. He has worked with both large and small research groups and successful start up research companies. He, personally, founded and helped manage several successful research and development companies.

At present, he is a member of the Board of Directors of several companies and leads a consulting company with clients in both the defense and civilian research and development sectors.

Prior to this he was a Distinguished Research Professor in Systems Engineering and Technology Management at Stevens Institute of Technology in Hoboken, New Jersey. He was the creator and first Director of Institute Technology Initiatives, a position reporting directly to the President. In this capacity he served as the chief technical advisor to the President in all matters having to do with Institute research initiatives, management of Institute intellectual property and commercialization of Institute technology. He retired from Stevens in 2005.

Prior to this, he was Director of the Defense Advanced Research Projects Agency (DARPA), the central R&D organization of the Department of Defense. Dr. Fernandez was appointed as Director of DARPA on May 10, 1998. Under Dr. Fernandez' leadership, DARPA served as the Department of Defense's premier change-leader, trailblazing paths in biological warfare defense, information security, precision strike and robotics.

Until his appointment as Director, DARPA, Dr. Fernandez held the position of President and Chairman of the Board of Directors for AETC Inc., a firm specializing in environmental surveillance, which he founded in 1994. Prior to this position, he was President and Chairman of the Board of Directors of Areté Associates, a Los Angeles-based applied research firm that Dr. Fernandez founded in 1976. Areté Associates has a national reputation in the use of advanced sensors and signal processing for the detection and classification of concealed targets. From 1975 to 1976, he served as Vice President at Physical Dynamics Inc., and from 1972 to 1975, he worked as a Program Manager for R&D Associates. Before that, Dr. Fernandez worked for the Aerospace Corporation and the Lockheed Corporation, specializing in re-entry physics problems associated with missile defense.

Dr. Fernandez was a member of the Chief of Naval Operations (CNO) Executive Panel from 1983 until his appointment at DARPA. In this capacity, he provided advice to the CNO on a variety of issues. He was Director of the Green Foundation, a non-profit endowment for Earth Sciences from 1995 to 2000 and is listed in *Who's Who in Science.* Dr. Fernandez is also a member of the New York Academy of Sciences.

In May 2000, Dr. Fernandez was awarded the Renaissance Engineering and Science Award by Stevens Institute of Technology. In January 2001, Dr. Fernandez was awarded the Distinguished Public Service Award by the Secretary of Defense. Dr. Fernandez has been awarded an Honorary Doctor of Engineering Degree from Stevens Institute of Technology in May 2001.

Dr. Fernandez received his Bachelor of Science in Mechanical Engineering and Master of Science in Applied Mechanics from Stevens Institute of Technology in New York, 1960–1961; and his Ph.D. in Aeronautics from California Institute of Technology in 1969.

Chairman BOEHLERT. Thank you very much.

Dr. Cotell.

Okay. Here is what we are going to do. We have got a call of the House. We will finish your testimony. Some people may wonder why I don't be more arbitrary with the five-minute rule. I am with Administration witnesses, because quite frankly, we know what they are going to tell us. They are going to tell us what a great job they are doing and all of that sort of thing. And in many cases, that is exactly the case. But you, we just—you have got—you are

more objective in your presentations, and that is what we learn from.

Dr. Cotell.

STATEMENT OF DR. CATHERINE COTELL, VICE PRESIDENT FOR STRATEGY, UNIVERSITY AND EARLY STAGE INVESTMENT, IN-Q-TEL

Dr. COTELL. Chairman Boehlert, Ranking Member Gordon, and Members of the Committee, thank you for the opportunity to speak with you this morning.

The National Academy study that recommended the formation of ARPA–E, also suggested that the Committee might look at In-Q-Tel as a model of elements of which you might want to emulate in forming your ARPA–E.

So for those who don't have Chairman Boehlert's familiarity with In-Q-Tel, let me spend a couple of minutes describing our mission, how we accomplish that mission for the intelligence community, and to make some observations about how In-Q-Tel's model might apply in the case of the Department of Energy's challenges.

In-Q-Tel is a non-profit, independent, strategic venture capital firm founded in 1999 by the CIA. We are presently funded by several agencies in the intelligence community, including the CIA, the DIA, FBI, National Counterterrorism Center, and the National Geospatial Information Agency. These agencies are limited partners.

In-Q-Tel invests in commercial companies that are producing technology products that are relevant to the intelligence community's mission. If you were to compare the CIA with any Fortune 500 company, what you would find in information technology is almost a complete overlap and the need for software to gather, analyze, sort, and distribute knowledge. So In-Q-Tel's approach is, rather than form a government-only solution to that challenge, is to look to industry and to invest in small start-up companies that are producing product for that commercial market and bring those products back into the government via investment. And typically, those companies are not actually focused on the government market.

What we can do as an investor is actually buy the product development roadmap so that the products will, in fact, meet the needs of the intelligence community as well.

The advantages to that are fairly clear: lower costs, easier integration, longer technology lifetimes, new versions that come out, all leveraged with success in the commercial marketplaces.

In-Q-Tel is overseen—our activities are overseen by an exception Board of Trustees. In fact, Norm Augustine, who is the chair of the National Academy's panel, is on our Board. We rely on an interface center at the CIA, known as the QIC. They provide us with insight into the end-user's needs, and that is a very important element of our operations. They also serve as the executive agent for the other agencies, letting us know what their challenges and pain points are.

In In-Q-Tel's six-year history, we have reviewed over 5,500 business plans. We have invested in 90 companies. We have delivered 130 technology solutions to our intelligence community limited

partners. And I think, very significantly, we have returned about $15 million into our investment pool from the returns on our early investments. And those returns are being used to further the support of the intelligence community mission.

Just to give you a little bit of—compare and contrast with DARPA, and I defer Dr. Fernandez's first-hand account of DARPA, In-Q-Tel is a private firm, whereas DARPA is a government agency. I think that I can say that DARPA funds very forward-looking research aimed at radical innovations that will be represented in products. And they, of course, focus on the DOD mission.

In the case of In-Q-Tel, we generally invest in companies that are already producing product. And we are, in that case, really looking for both commercial success and relevance to the intelligence community's mission. In some cases where we do feel that there is a compelling need in the intelligence community and we find a robust technology but there is not yet a company, we will work to spin a company out around that technology, but only if there is a compelling commercial market.

In-Q-Tel's venture capital model is not a substitute for basic research. Rather, what we do is leverage government and private sector investments in research. In fact, for every $1 that In-Q-Tel invests, $8 of private investment are leveraged in order to bring products to the market that the intelligence community can purchase.

The majority of our companies actually have their roots in fundamental research that was funded by NSF, DOE, ONR, and DARPA.

On the development timeline from conception of an idea to that commoditized product, we don't—we typically enter, more or less, at the point where a working prototype can be demonstrated. So we are later stage, typically, than when DARPA gets involved. And in some cases, we will provide very directed gap funding to bridge the , so-called, "valley of death" that occurs at about the time that the fundamental research funding is declining and before the point at which a technology is mature enough to be represented in an acquisition program, for example.

So the question has been raised a couple of times this morning as to whether a DARPA model or an In-Q-Tel model would apply in the case where the government is not the customer. And I can certainly that being able to offer the intelligence community as early adopters and customers, i.e., revenue generators, to our portfolio companies and to our co-investors is a huge value proposition that In-Q-Tel brings. And that wouldn't necessarily be the case in the energy market.

I would note by contrast that the market, in the case of energy, is really very diverse. It ranges from the individual consumer who is going to buy an alternative fuel vehicle to large utilities who are providing power to the grid. And in that case, also, there is no single procurement vehicle as there is in the case when the government is the buyer. And I would also note, as others have, that policy and economic factors greatly influence the size of that market. And in that regard, I think that it might be instructive to look at healthcare as an example. So in that case, rather than a sort of technology transfer in, to the government case, what you are looking at is basic research being transferred out to private companies

who are going to produce a product. And in that case, too, you have the effect of policy and other influences. How much insurance is definitely affects the size of the market if I can actually afford to buy a drug or a therapy.

So at the risk of oversimplification, when it comes to barriers to market entry, I think it all comes down to money, and whether there is money in that market will really determine whether companies are going to get involved.

So I hope, in conclusion, that I have provided the Committee with a description of In-Q-Tel and that it is adequate to show the strengths of that model for the intelligence community. Certainly, fundamental research remains a requirement for creating game-changing innovations in all fields, including energy. And based on In-Q-Tel's success at using venture capital tools to accelerate the rate at which the intelligence community gets access to new technology, I think there may be some merit in considering incorporating some elements of In-Q-Tel into an ARPA–E, if that is where we are going with this.

In particular, I think there is merit in incorporating a mechanism for the kind of technical and market diligence that In-Q-Tel conducts prior to making an investment. For example, the dynamics of venture capital syndicate investing could provide an effective commercial peer review that would be sort of parallel to, or at least at a later stage than, the kind of scientific peer review that goes on when one decides to fund a proposal. And in particular, I think the investor perspectives could inform the selection of products from those of which that are at the edge of the "valley of death" that you might want to consider funding to get to the point of actually making it into a product.

So finally, if I may, I would like to point out that In-Q-Tel was founded in 1999 at the height of the internet boom when the best and the brightest minds in this country were being attracted to information technology. And indeed, In-Q-Tel, itself, was founded to tap into that IT genius in the marketplace. So as the Committee considers alternative approaches to ARPA–E, I would like to encourage that whatever model you adopt that it foster a climate of entrepreneurship so that this decade's best and brightest will be attracted to energy research.

So I thank you for the opportunity to speak with you and welcome any questions you might have.

[The prepared statement of Dr. Cotell follows:]

PREPARED STATEMENT OF CATHERINE COTELL

Introduction

Good morning, Chairman Boehlert, Ranking Member Gordon, and Members of the Committee. I thank you for the opportunity to appear before you this morning to discuss the question of how the government may help spur innovation in the energy sector, and may best obtain access to the most innovative energy research and development available.

I would like to first offer a brief description of my own background which may help put my remarks in context. I spent the first ten years of my professional life conducting research, first in graduate school at MIT, funded in part with DOE grants, and later at AT&T Bell Laboratories and the Naval Research Laboratory. Because my work has included issues of technology transfer, intellectual property, Cooperative Research and Development Agreements, and other linkages between researchers and the commercial sector, I had already become fascinated by the novel approach to technology development and deployment taken by In-Q-Tel prior to join-

ing the staff in 2003. At In-Q-Tel, I have focused on searching for nascent technologies at universities, federal laboratories, and other emerging sources to help orchestrate their commercialization for sustainable delivery to the Intelligence Community.

Background

In-Q-Tel is a strategic venture capital firm that makes investments to benefit the United States Intelligence Community (IC). Here is how it works: As an independent, non-profit, government-funded firm, In-Q-Tel engages start-ups, emerging and established companies, universities, and research labs to identify technology innovations and products that can solve the Intelligence Community's most challenging problems. In-Q-Tel then employs venture capital investments, often coupled with product development funding, to create sustainable technology solutions to be delivered to the Intelligence Community from thriving commercial companies. Our focus is on companies and technologies principally directed at the commercial market that also address the needs of our government partners, because of the significant benefits of commercial technologies I address below.

In-Q-Tel is flexible in how it structures its investments to foster win-win relationships, providing the Intelligence Community with early access to emerging technologies and providing In-Q-Tel's portfolio companies with government business development guidance. We are very different than a government agency, but we are using the genius of the marketplace to benefit the government, and it is working. For every dollar In-Q-Tel invests, In-Q-Tel leverages an average of eight dollars of private investment to bring technologies to the market, helping to lower both development costs and total life cycle costs for the benefit of the Intelligence Community. In addition, returns to date on our investments have allowed In-Q-Tel to add approximately 15 million dollars to its investments pool which is being used to further its mission.

In-Q-Tel is bound by a Charter agreement with the CIA, which sets out the relationship between the two organizations and which is supplemented by annual funding through the Intelligence Community. In-Q-Tel is not part of the CIA and is not a government agency, but the five-year span of each renewable Charter agreement between the CIA and In-Q-Tel provides a beneficial perspective that facilitates long-term planning. And as a government contractor operating as an independent non-profit corporation, In-Q-Tel receives regular oversight from the CIA, which keeps Congress informed of the company's activities.

The company is governed by an independent Board of Trustees composed of former cabinet officers and officials from defense and the Intelligence Community, as well as CEOs of major companies, university leaders, and leaders of the investment industry.

As you know, Mr. Chairman, In-Q-Tel grew out of the recognition in the late 1990s by the Director of Central Intelligence George Tenet and others that the CIA and the rest of the U.S. Intelligence Community needed the very best technology available to fulfill its mission. This led the Director to ask a group of distinguished Americans to create a company that would explore creative ways to access private sector innovation and technology development—a process, resulting in In-Q-Tel, led by former Lockheed President and CEO Norm Augustine. Today's hearing acknowledges the insightful contribution to this discussion of the National Academies panel on American Competitiveness also led by Norm Augustine, and the panel's recent report, *"Rising Above the Gathering Storm."* We are incredibly fortunate that Norm Augustine has served on our Board of Trustees since In-Q-Tel's founding, and that he has been joined on our Board by such visionaries as Lee Ault, Anita Jones, Charles Vest, Jim Barksdale, Bill Perry, and others.

In-Q-Tel has also been the focus of a number of thoughtful studies that describe and scrutinize the organization, examining its structure and effectiveness. In one example, an assessment was made by a panel from Business Executives for National Security (BENS), a national, non-partisan, and not-for-profit organization of business leaders—30 of whom formed the independent panel after the CIA selected BENS to conduct the congressionally mandated study. The report, "Accelerating the Acquisition and Implementation of New Technologies for Intelligence: The Report of the Independent Panel on the Central Intelligence Agency In-Q-Tel Venture," was submitted to the CIA and Congress *(www.bens.org/highlights_InQTel.html).* The panel concluded that In-Q-Tel had achieved significant early progress and that "creating a model like In-Q-Tel makes good business sense." In a second example, the Harvard Business School published a Case Study that examined In-Q-Tel's history, strategy, and effectiveness in the context of other federal technology development programs such as Small Business Innovation Research set-asides, the Advanced

Technology Program, DARPA, and Federally Funded Research and Development Centers (Case 9–804–146, *http://harvardbusinessonline.hbsp.harvard.edu).*

Since our founding in 1999, we have delivered more than 130 technologies responding directly to CIA and Intelligence Community missions, bolstered by more than 90 pilot programs and more than 30 specific technology adoptions. Technology delivered by In-Q-Tel, for example, makes it possible to fuse data from maps, images, text and other sources; visualize information in ways not previously possible; rapidly process vast amounts of information in multiple languages; make sense of seemingly unconnected information; and identify the most critical intelligence faster and more effectively.

The In-Q-Tel approach

In order to help identify technology solutions that can address capability needs of the Intelligence Community, In-Q-Tel has a broad outreach policy. In addition to soliciting business plans via its web site *www.In-Q-Tel.org,* In-Q-Tel actively scouts for technologies and investment opportunities by capitalizing on its technology network that includes other venture investors, university faculty and technology commercialization offices, national and corporate laboratory researchers and their licensing offices, and program managers at Government funding agencies. We have also engaged with nearly 90 commercial companies, most of which were previously unknown to the government, and 11 universities and research labs, which In-Q-Tel identified through its commercial and academic outreach programs. In-Q-Tel has also received and subsequently reviewed over 5,500 business plans. As part of this outreach, we have also cultivated a network of more than 200 venture capital firms and 100 labs and research organizations, further broadening the Intelligence Community's access to innovative technologies.

Before In-Q-Tel makes an investment, members of three teams conduct diligence to ensure that the investment is on firm footing—to use an analogy, three legs of a stool must be supported. The first team consists of CIA employees who are members of the In-Q-Tel Interface Center, or the "QIC" (pronounced "quick"), which serves as the executive agent for our interaction with partners throughout the Intelligence Community. The QIC leads an annual and ongoing "problem set" definition process through consultation with end users throughout the Intelligence Community, to ensure that the solutions being evaluated by In-Q-Tel experts are likely to be adopted by users among our government partners. The QIC provides In-Q-Tel with knowledge about the technology needs of the CIA and other government partners in the Intelligence Community through regular and ongoing discussions with the leadership, the policy-makers, and the operators in our partner organizations—and together we have established an extensive demonstration, pilot, and adoption program to facilitate technology transfer.

The team responsible for the second leg of the stool consists of In-Q-Tel's staff of technology experts who vet each technology opportunity against Intelligence Community needs, comparing alternative approaches and validating technical claims to ensure the technical robustness of the solution.

The third leg of the stool is the responsibility of In-Q-Tel's venture team members who examine the commercial market, review the company's business plan and evaluate the management team to gauge the potential for long-term success in the market.

One of the strengths of the venture investing model is that In-Q-Tel's own technology, market, and business assessments are validated by the diligence conducted by its co-investors. Over the six years that In-Q-Tel has been in operation, In-Q-Tel has developed a reputation for conducting among the most rigorous technical due diligence in the investment community, and In-Q-Tel has found that other investors rely on In-Q-Tel's assessment of the soundness of technologies it examines.

Most of In-Q-Tel's investments involve evaluation of opportunities in which the technologies are already being commercialized by start-up companies. In the Information Technology arena, for example, comparing the CIA and our other government partners with any Fortune 500 company, one finds a 70 to 90 percent overlap in information technology needs for collecting, sorting, analyzing and distributing knowledge. Rather than seeking point solutions or one-off custom products designed explicitly for the Intelligence Community, In-Q-Tel invests in companies that build successful technology solutions intended for the high growth commercial market and introduces these solutions to the Intelligence Community.

In some cases, however, In-Q-Tel engages at a very early stage, before the technology has been spun out of the laboratory. In those cases in which the technology and the commercial market are robust and the Intelligence Community need for the solution is critical, In-Q-Tel will strategize to move the technology from the laboratory into a spin out, by assembling a management team and providing seed funding.

In-Q-Tel uses its network in the venture community to assist with these activities and will engage only if the spin out can address a substantial commercial market.

The roles of In-Q-Tel and DARPA contrasted

As the Committee has noted, some have suggested that an ARPA–E should be designed to foster directed basic research, and other proponents suggest its role should be to get products into the marketplace. In-Q-Tel was founded to address a specific and unique challenge that is somewhat related: namely, how to provide the U.S. Intelligence Community with access to the technology innovations being brought to the commercial market by small, start-up companies, or other sources of innovation such as national labs and universities, who may not target the government for sales. Like any other venture investor, In-Q-Tel "cherry picks" technologies with high potential for commercial success. Because In-Q-Tel is a strategic investor for the Intelligence Community, In-Q-Tel selects from the entire range of commercially viable technologies those that have relevance to Intelligence Community mission.

In-Q-Tel's venture capital model is not a substitute for fundamental research funding, but rather leverages government and private sector investments in research. In fact, the majority of the companies in which In-Q-Tel has invested have their roots in fundamental research conducted at universities and laboratories supported by NSF, DOE, ONR, and DARPA. Moreover, before the products are delivered back to the government, other private investment capital in addition to In-Q-Tel's has been invested in the companies, leveraging additional private sector resources to deliver a better product to government.

As you know, Chairman Boehlert, the President's Science Advisor, Dr. John Marburger, testifying to your committee just last month alongside Secretary of Energy Samuel Bodman regarding the 2007 budget, noted the critical role that basic research plays as the foundation of our nation's economic competitiveness—a message President Bush supported in his State of the Union address through the announcement of his American Competitiveness Initiative and the Advanced Energy Initiative. The American Competitiveness Initiative calls for a doubling, over ten years, of the support of basic research in the physical sciences funded through the National Science Foundation, the National Institute for Standards and Technology, and the Department of Energy's Office of Science; and the Advanced Energy Initiative provides for a 22 percent increase in clean-energy research at the Department of Energy. These initiatives reflect the need to accelerate our breakthroughs in the vital arena of energy independence and innovation which your committee is focusing on now.

On the development time line from incipient idea to fully productized, off-the-shelf commodity, In-Q-Tel typically engages sometime after the demonstration of a working prototype. That is, In-Q-Tel does not typically invest in early research the way that DARPA or other government funding agencies do, but rather, takes the output of early research and supports its development into technology products and sustainable commercial outlets from which to buy those products. In some cases, In-Q-Tel provides very directed "gap funding" to assist in bridging the so-called "valley of death" between the basic research funding and the point at which the technology opportunity is sufficiently mature as to readily attract institutional investors or, in the case, of DARPA, be ready for delivery under a DOD procurement or acquisition program.

As an investor, In-Q-Tel can influence the product development roadmap to ensure that the commercial products will indeed meet the Intelligence Community's needs while adding value for the commercial customers as well. Among the advantages of commercial technology are lower initial and long-term costs, easier integration, longer technology lifetime, faster development, better user interfaces, incremental upgrades, and next-generation improvements, all developed by leveraging success in the commercial marketplace. Our success stems from linking commercial viability and technical excellence with our government partners' needs.

When government is not the primary or early user of a technology

One of the elements that In-Q-Tel considers essential for its success is a deep understanding of our government partners' needs, challenges, and pain points, which we derive through our interactions with the QIC and the interface centers at other various agencies we work with. Indeed, being able to offer the U.S. Government Intelligence Community agencies as potential early adopters of the technologies is a unique value proposition In-Q-Tel brings to its portfolio companies and co-investors. These early revenue opportunities coupled with the validation by a discerning customer are quite useful as these companies work toward commercial market penetration.

By contrast, the "customers" for the products of energy research are diverse, ranging from the individual consumer who buys an alternative fuel vehicle to the large utility companies who provide power to the grid. That is, there is no single procurement mechanism, and this market can be significantly impacted by policy and regulation that may provide incentives or disincentives to early adoption.

From the customer perspective, the challenge that motivates the formation of an ARPA–E is similar to that faced by the National Institutes of Health (NIH). The fundamental research funded by NIH must be transferred to the commercial sector for maturation and productization before the customer (ultimately the taxpayer who has need of a therapy) can benefit. The pathway from research to product in the case of health care typically involves costly and time-consuming clinical trials supported by private investment dollars invested with the expectation of return in the form of profit from lucrative sales in the pharmaceutical or medical device markets. Moreover, similar to the energy sector, the health care sector is strongly impacted by external factors such as cost reimbursement (insurance) that can serve as incentive or disincentive to making such investments.

Barriers and incentives

At the risk of oversimplification, and assuming a healthy supply of new technologies being created as a result of basic research funding, the barriers to such new technologies being brought to the market can all be distilled down to one factor: money in the marketplace. Companies will only take on the task of productizing a new technology if there is a high probability that they will make money selling the product. That statement is true regardless of whether the customer for the product is the government or the wider commercial market.

Returning to the NIH example, a company is likely to productize a new therapy only if there is a likelihood that they will make money selling the therapy; that is, the patient population is large enough and both willing and able to pay for the therapy and the cost margins are such that the company will make a profit. The health care market, like the energy market, is subject to influence by policy initiatives; an example would be expanding health insurance coverage to enable patients to pay for new therapies which would have the effect of increasing the size of the market and the probability that a company entering that market with a new therapy could make money. The market in the energy sector is subject not only to influence by policy initiatives but also by global economic trends.

One of the observations that led to the founding of In-Q-Tel is that if the government is the only customer and the government has a critical need for the product, there is a higher likelihood that the government will overpay relative to the situation in which the government's critical needs can be satisfied with a product that can also be sold in the larger commercial market. In-Q-Tel was designed to ensure that the government can get access to commercial products that will address the government's critical needs at the lowest cost and greatest impact possible. In-Q-Tel does not invest in companies that do not have a commercial market; the In-Q-Tel model does not apply to those cases.

The In-Q-Tel model as part of the solution

I hope that in this discussion I have been able to describe the strengths of the In-Q-Tel model for responding to specific needs within the Intelligence Community. Certainly, fundamental research remains a requirement for creating game-changing innovations in all sectors, including energy. Based on In-Q-Tel's success at using venture capital tools to accelerate the rate at which In-Q-Tel's customers get access to new technologies, this committee may wish to consider incorporating into the design of ARPA–E some elements of the In-Q-Tel model to assist with bridging the gap between basic research and commercial viability. We can summarize our approach as follows. By utilizing equity investments, sometimes coupled with work programs and market guidance, In-Q-Tel fosters the development of strong companies which produce commercially viable technologies that at the same time solve critical Intelligence Community mission challenges. There may be parallels for the energy market.

Note, however, that the general direction of In-Q-Tel technology transfer is from the commercial side to the government (tech transfer in), while the technology transfer challenge for energy is in many cases to convert energy research into products that can be sold commercially (tech transfer out)—to a customer set, or market, that is more diverse and fractured that in the Intelligence Community, requiring an examination of the implications for the value proposition to the portfolio company.

There may be merit to incorporating into ARPA–E a mechanism to provide the kind of technical and market diligence, aimed at commercial viability, that In-Q-Tel

conducts prior to making its investments. This kind of diligence based on investor perspectives could be very valuable in informing the selection of research projects for continued development with ARPA–E support. There is a lot to be said for the screening that accompanies investing one's own capital in a project, and the dynamics of a venture capital investing market can provide effective commercial peer review that for technologies at a later stage of maturity (at the edge of the "valley of death") parallels the benefits of scientific peer review that occurs on the basic research and development end of the spectrum.

Returning to the analogy of a stool that for stability requires all three legs to be well-supported, it is a third leg—the customer input—that would necessarily differ in the energy market from the In-Q-Tel model because of the diversity of the customer base, the lack of a single procurement mechanism and the susceptibility of the energy market to manipulation by policy initiatives and global economic events.

Conclusion

Again, I thank the Committee for the chance to speak with you today, and I congratulate you for tackling the crucial national need for groundbreaking innovation in the energy market. Creating additional avenues for basic science and for commercial opportunities may help attract the best and the brightest to energy research, as it has in the past to such historic efforts as the space race of the 1960s and the Internet boom of the 1990s.

BIOGRAPHY FOR CATHERINE COTELL

Dr. Catherine M. Cotell received her B.A. in chemistry and mathematics from Wellesley College and her S.M. and Ph.D. degrees from the Massachusetts Institute of Technology in metallurgy and materials science and engineering, respectively. After two years as a member of technical staff at AT&T Bell Laboratories, Dr. Cotell joined the staff of the U.S. Naval Research Laboratory (NRL), where she conducted research in surface modification and thin film coatings for electronic, optical and biomedical applications. She joined the staff of the Technology Transfer Office at NRL in June of 1997 and assumed the position of head of the Office in April of 1999. As head of Technology Transfer, she evaluated, managed and marketed NRL's intellectual property portfolio, negotiated Cooperative Research and Development Agreements (CRADAs) and patent license agreements, and facilitated collaborations and interactions between NRL researchers and the commercial sector. In July of 2003, Dr. Cotell joined the staff of In-Q-Tel, the venture catalyst for the Central Intelligence Agency (CIA) as Vice President for University Outreach. Dr. Cotell launched In-Q-Tel's University and Federal Laboratory Outreach program to search for emerging technologies at universities and federal laboratories and orchestrate their commercialization for sustainable delivery to the Intelligence Community. Dr. Cotell's responsibilities at In-Q-Tel have expanded to include providing strategic direction for the company as Vice President for Strategy, University and Early Stage Investment.

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The Honorable Sherwood Boehlert
Chairman
House Committee on Science
U.S. House of Representatives
2320 Rayburn House Office Building
Washington, D.C. 20515

Chairman Boehlert:

As per the requirements for a financial disclosure letter from each person who testifies before Congress who is not representing a government entity, I write to inform the Committee that I am an employee of In-Q-Tel, which is an independent not-for-profit entity registered with the IRS as a 501(c)(3) organization. In-Q-Tel receives its funding through the CIA, and our partners include the CIA and other members of the federal Intelligence Community.

I have been asked to testify before the House Science Committee on March 9, 2006, regarding the structure and operational effectiveness of In-Q-Tel in fulfilling its mission.

Respectfully,

Catherine Cotell

Dr. Catherine Cotell
Vice President for Strategy,
University, and Early Stage Investments

DISCUSSION

Chairman BOEHLERT. I thank you, and I thank all of you for being persons of vast information for us.

Now we have got to respond to the call of the House for a vote. I think we should be 15 minutes or less. The staff will talk to you about the comforts of our lounge. It is not luxurious, but at least it is there. And we will try to accommodate you on a coffee or some sort of liquid. And we will be back in about 15.

[Recess.]

Chairman BOEHLERT. The hearing will resume.

I wish we had note takers back in the lounge, because my understanding is while we were over voting, we had rather spirited and very interesting conversation among our panelists. And that is what we are here to encourage.

Let me start out by asking all of you this.

You know, I know that most of you support, with some obvious exceptions, Dr. Mowery, the establishment of ARPA–E, although, for somewhat varying purposes and with somewhat varying qualifications. And as I mentioned in my opening statement, we are faced with setting priorities, and Dr. Chu, as you noted, new money you would like if we have this ARPA–E.

So let me ask all of you. If we have to make a choice, and we have to make choices around here all of the time, we are—at least I am inclined to agree with the panel and the report, that the highest priority is for the Office of Science. We have got a 14 percent increase, about a $500 million figure increase. And you are saying that about $300 million would be the minimum to start. So would you support an ARPA–E if the money proposed came from the Office of Science?

Dr. Chu, I think I have your answer.

Dr. CHU. Yeah, it is very simple: no.

Chairman BOEHLERT. Yeah.

Dr. Mowery.

Dr. MOWERY. No, I think it would be interesting to see whether some of the design principles that motivated the panel to suggest an ARPA–E could be incorporated into the management of a portion of the funding increases requested for the DOE generally, for the civilian side of DOE.

Chairman BOEHLERT. Ms. Kenderdine.

Ms. KENDERDINE. I would not support taking money out of the Office of Science to fund this if it were insufficiently funded. I think I said in my testimony, you can't set this program up to fail. And I assume that the Academy knew what it was talking about when it recommended certain funding levels. And there has to be a critical mass in order to make a difference. This is supposed to be transformational. And insufficient funding would constitute a failure, and I wouldn't support that.

Chairman BOEHLERT. Thank you.

Dr. Fernandez.

Dr. FERNANDEZ. I think I agree. Insufficiently funding two activities instead of sufficiently funding one is the worst of all management decisions.

Chairman BOEHLERT. Thank you very much.

Dr. Cotell.

Dr. COTELL. I would third that. I don't claim to know enough about the Office of Science's operations, but from my perspective where we are trying to transition technology, you can't dry up the pipeline. It is critical to have that basic work done.

Chairman BOEHLERT. Thanks very much.

Now the next question is an obvious one.

What makes you think that we could insulate ARPA–E from energy politics as they try to challenge incumbent technologies? I mean, that is a tall order to fill.

Dr. Chu.

Dr. CHU. You are right. It is a tall order. I look to the leadership of Congress.

Chairman BOEHLERT. Thank you.

You know, I am just reminded of the fact, and when we—our professional staff and I sat down and started talking about this hearing, and the supply demand, I said, "Look. We have got technology right now, off the shelf to make automobiles more fuel efficient. I think we are nuts for not doing it." And I have, year after year, offered an amendment to various legislative initiatives to increase CAFE standards. I mean, we don't have to go out and invent something new. And so—yeah.

Dr. Mowery, what do you think?

Dr. MOWERY. Well, I think it is very difficult to insulate it. I think, as your question suggests, one of the problems, historically , has been that changing priorities and changing prices tend to produce an ebb and flow both of funding and of interest and also priorities. And the result is that we are not moving things out as rapidly as we could into use.

Chairman BOEHLERT. You know, Ms. Kenderdine, she put it very well, "Picking winners threatens to strand existing industry assets." And that, perhaps, is why the head of ExxonMobil dissented from this recommendation.

Anything you would care to add on that one?

Ms. KENDERDINE. I am not surprised that ExxonMobil was a dissenter. They have never supported anything that I have supported, but the—it is very difficult. I would just urge the Committee to consider how imperative it is that we invest in new ways of doing business, and that, at some point, if you empower a research organization in a way that assures that it will pick the best winners, that might be what we need to be doing right now.

Chairman BOEHLERT. Dr. Fernandez.

Dr. FERNANDEZ. Like I said at the beginning, I am not much of an expert in the energy business, but I can tell you this. For the experts, if it turns out that the next 30 years we think is a time where there is going to be major changes in the energy markets, okay, which will put the United States in funny positions and that technology could help us maintain a favorable position there, then I think that becomes the major justification for looking forward as compared to worrying about the two-years-from-now problem, the way the companies are thinking now.

Chairman BOEHLERT. Thank you.

And Dr. Cotell, anything you care to add?

Dr. COTELL. I think, again, from In-Q-Tel's perspective, which is that of a kind of novel experiment that was started, a long-term commitment is important. And inasmuch as politics might impact that, I would say if you do this, you have to commit to it for a few years and make sure that you give the organization time to be strategic in what it does and to morph its model a little bit to make sure that it does the right job.

Chairman BOEHLERT. Thank you.

Mr. Gordon.

Mr. GORDON. Mr. Chairman, I was shocked, shocked to hear you say that the Chairman of ExxonMobil voted against looking at alternative fuels. You know, that—I am just—I am—I don't know what to say. I mean, it follows along that cow commercial that says, "Eat more chicken." I mean, of course that is what—you know, it is a corporate policy not to go into that kind of research development.

Let me move to another area.

I think most folks—they will say it, and they probably agree with it, that a part of national—our national defense is reducing our dependency on foreign oil. Saying it and then trying to believe it and then doing something seems to be something else, and I think that we need to take it a little bit further.

The wrong question was put to you earlier in that where would you shift funds around the Department of Education or the Department of Energy. That was the wrong question. The right question is would you rather put more money in looking at alternative fuels and energy dependency than having your capital gain stay at 15 percent rather than go to 20? Would you rather spend more money in the area of education—or rather of energy than spending $50 billion on a Star Wars program that has never once demonstrated that it works? You know, would you rather spend some more money on energy independence than you would on other superduper weapons systems that—when we don't have a major power that is opposing us? Now—you know, so you were given the wrong question.

Now let me ask you the question. Do you think it might be worth rearranging some of our priorities to invest more in energy dependency—independency?

Dr. CHU. Well, that was the very strong opinion of the Augustine Committee. It wasn't—we were never thinking you take money out of basic research in the Office of Science and move it over into ARPA–E, but within the vast amounts of money that the U.S. Government funds in total, $1 billion is not much, considering the stakes that are involved. And——

Mr. GORDON. Well—yeah, we are not going to spend time on this. If anybody would like to disagree with Dr. Chu, just raise your hand, otherwise—would you? Okay. Okay. Then we will just assume that everybody thinks that this would be a priority that we should look elsewhere and that we should not be putting the bind of cannibalizing ourselves.

Let me now move to my final question, because I have a limited amount of time.

There seems to be a general consensus that an ARPA–E program would be beneficial, if it was done right, and everybody can decide,

you know, how—what is "done right." I was talking to Mr. Bartlett—Dr. Bartlett coming over here, and you know, we also share that same kind of concern about are you going to get it right? But if you don't do something, we are—we really have a problem. And so I think that we need to move forward, and hopefully we will get it right.

The bigger question was this area of demand. And you know, will there be a market for this, and what do we—where do we go with it? So Dr. Chu gave us some suggestions about the type of research that he would like to see go forward. Let me ask a question in general. How do we address this demand issue? I will just leave it at that.

Dr. CHU. Okay. I know——

Mr. GORDON. You can go ahead, and then we will just flip it down through.

Dr. CHU. Okay. Let me give you a good example.

The—clean coal. We need to develop clean coal technologies. The—not only for us, but for the entire world, because the countries that have the most coal supplies are the United States—in this order: United States, China, India, Russia. And it would be very difficult for those countries, including us, to turn our back on coal, if it is there. So we need to develop clean coal technologies.

If a carbon tax or a carbon cap and trade is not put in place, right now the gasification of the coal and the capture of the CO_2 and the sequestration is estimated to be roughly 30 percent higher, or maybe more, but of that order. There will be no industry incentive for the next coming decades.

In the meantime, if industry invests in the next one or two decades in conventional coal plants, you will have cast the die for the next 40 or 50 years. So in this case, regulatory tax, whatever, fiscal policy, is very important. Then industry will be very motivated to develop efficient coal.

However, there still needs to be an ARPA-like component to this. Why? Because of sequestration. Right now, oil companies, BP, for example, is using carbon sequestration to use it for enhanced oil recovery. So as they bring out—natural gas, for example, has a lot of extra CO_2. They will pump that CO_2 back in to get more oil back out of the ground. But they would probably not do research in sequestering carbon dioxide in the major potential reservoir, namely in the salt water beds deep under the Earth. That is something the Department of Energy or—should have to do initially until it looks like it might be able. But say—that is something that is a long-term research project you don't see industry investing in for the next decade.

Mr. GORDON. Okay. Let us just go on down the line.

Dr. MOWERY. I agree with Dr. Chu that some set of policy is a combination of fuel economy standards, carbon taxes, other fiscal or tax-related policies is essential in order to complement the necessary investments in R&D on the supply side, if you will, with the creation of stronger market signals for adoption on the demand side.

We tax cigarettes heavily, and taxes on cigarettes have gone up substantially in the last decade, precisely because of a political consensus that growth in consumption of cigarettes is dangerous to the

public health and to the larger welfare of the citizens. Energy, I think, has a very similar set of arguments underpinning it. We—tax it more heavily with a recognition—in the recognition that continued growth in consumption on the current trends is toxic, from a national security, environmental, and economic perspective.

Mr. GORDON. You mean as they have done in Europe and most every other country in the world?

Dr. MOWERY. Precisely.

Mr. GORDON. Okay.

Ms. KENDERDINE. The recent data shows gasoline prices have doubled and gasoline consumption has gone up. And so, from an—from a gasoline/oil perspective, the size of the tax that you would have to impose would pale in comparison to new—you know, new money at a billion dollars to fund an ARPA–E program. It would be politically unpalatable, very, very difficult to do, in any environment. And so I think you need other kinds of market conditioning than a huge tax on gasoline, for example, a carbon cap and trade carbon tax is a way to spread that incentive, shall we say. There are a whole host of market pushes and pulls that we need. The technology development, the R&D that we all want to see invested in as necessary, it is not sufficient. That is kind of another stovepiping problem within the government. All of those policy imperatives are established at different locations in the government, and they are not sequenced with the investments that we are making in R&D.

Mr. GORDON. Excuse me. If we could—I know we need to move along. I just wanted to get the others.

Again, the question goes back to are we going to have, unlike with the Defense Department where you have a built-in market, is this going to be useless since we don't have a market here?

Dr. FERNANDEZ. The one thing I think is different, and I am not sure how it is going to progress in the future, is in this world now of energy, there are at least two emerging powers with insatiable appetites for energy. And I think that is going to change the whole dynamic of energy markets. I don't know how, because I am not an expert, but I can start to see some areas where if the United States doesn't start thinking ahead and doing things that take long-term investment, all of a sudden we are going to be buying some of our technology from other places, critical to our energy, and I am not sure if that is in the best interest of the United States.

Dr. COTELL. I really don't have a lot to add, and I haven't studied the energy market. What I have studied is the, sort of, dynamics of small companies entering markets. And I think there are some good examples here where, you know, if I can drive on the HOV lane, I am incentivized to buy an alternative fuel vehicle. And I think, maybe in conjunction with an ARPA–E, where your focus is really developing the innovations, and I hope working to transition those innovations, that you can experiment with some of the policy incentives that you would provide to companies to get into the market.

Chairman BOEHLERT. Thank you very much.

The gentleman's time has expired.

Ms. Biggert.

Ms. BIGGERT. Thank you, Mr. Chairman.

I am a strong advocate of the advanced fuel cycle for nuclear, and I think that is something that we really have to address right away and work on. And I think the Science Committee has been trying to bring attention to the problems that the Department of Energy faces with developing and deploying a fully integrated advanced nuclear fuel cycle. So—but I have been pushing to have the nuclear energy program to conduct a comprehensive and rigorous systems analysis of the advanced fuel cycle, because all of the technologies in the nuclear power system have to work together.

I would like to start with Dr. Chu and ask you how—could you kind of walk through how ARPA–E would be a better solution than the improved planning and analysis and prioritization of the existing programs?

Dr. CHU. Yeah. Okay.

There are two things. First of all, the current existing technology around the world, there are light water reactors. The current utility companies are—will not place orders for anything other than light water reactors, unless they have some assurances that a new technology will come to being. Now in the short-term, the Department of Energy is building a test reactor at Idaho National Lab to test a new, so-called, pebble bed reactor that is ceiling gas cooled. It has been—these have—designs have been out there for a decade or more, but there hasn't been a real solid test of the robustness of this. That is an intermediate—very—it is a short-term, intermediate thing that you—that, we see, can go into the marketplace hopefully within, you know, five or six years, or less than 10 years.

Now if you go to the larger issue, and—of complete fuel cycling, if you say that we are going to have only one repository, like Yucca Mountain, the capacity would—of the statutory limit would be over—it would be filled up by——

Ms. BIGGERT. 2010.

Dr. CHU.—2010——

Ms. BIGGERT. Right.

Dr. CHU.—and the physical limit by 2020, meaning the thermal limit. There are possible technologies that you use faster neutrons, design a small subset of reactors to burn down the waste products, and especially to decrease the lifetime of the nuclear—the spent waste products from—so it becomes something from a couple hundred thousand-year storage problem to a 500-year problem. There is a possibility there, and this long-term research and the simulation of these faster neutron reactors is something where—that would be something I could see going to ARPA–E.

Ms. BIGGERT. But they are already working on——

Dr. CHU. They are working at it, right. But it depends. I mean, right now, there is a——

Ms. BIGGERT. I guess the question I am asking is how would ARPA–E do it better than the programs that are trying——

Dr. CHU. Well, I wasn't really thinking of ARPA–E in terms of the nuclear sense.

Ms. BIGGERT. Okay.

Dr. CHU. I was thinking more of ARPA–E of initially like the analogy of a venture capital fund. One—these problems, like ITER, like nuclear fuel cycling and all of these other things that are now well identified, you can assert to establish a mechanism, you know

which way to march, but if you want to develop a totally new plan that would replace this corn in—for growing energy, that is more out of the box or a totally new technology. And so I—we are thinking of ARPA–E as mostly funding things like that, just totally off the wall, like the old DARPA did.

Ms. BIGGERT. But isn't that still a transformational technology to move the nuclear?

Dr. CHU. It is, but—and—but I think the Department of Energy sees this as one of its priorities and is moving forward with its current resources. But there is—we are not—I guess what I am saying is we are not fully tapping the basic science, both within the Department of Energy and within the NSF, within NIST. We are not—there is a potential for recruiting some of the best and brightest young scientists, who, just as we recruited them in war time to work on the radar and the bomb, I think many scientists are beginning to wake up and say, "This is so important that I really want to work on this."

Ms. BIGGERT. Don't we need something really like the Sputnik, too, I mean, to bring all of this together with nuclear energy?

Dr. CHU. Well, that is the trouble. We are not—we don't have a sudden thing like Nazi Germany or Sputnik.

Ms. BIGGERT. Maybe that is fortunate, but——

Dr. CHU. It is fortunate, but we are in a slow boil mode, and I am so glad, starting with the President and his initiatives and—but with all of the forces at work here, that we are beginning to wake up, even though there is not a sudden emergency, it is an emergency.

Ms. BIGGERT. Well, maybe the *"Gathering Storm"* is really a good analogy. And I am glad to see that you have some connection to Stanford, my alma mater, because I was worried about the two—the both of you sitting there from Berkeley, and you know, it brings back old competition.

Chairman BOEHLERT. Thank you very much.

The gentlelady's time is expired.

Dr. MOWERY. All of my degrees are from Stanford.

Chairman BOEHLERT. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chair.

And I think Stanford is well represented here, in terms of background. My—so you know——

Dr. FERNANDEZ. You have got one over here, too.

Mr. HONDA. And it is all from the San Francisco Bay area. So that is good, too.

I found the discussion by all of you very interesting and sort of engaging, and I think where I probably understand best right now is that DOD has DARPA, DARPA has one client, one—and one mission and makes clarity easy. And what I hear you saying is that with ARPA–E, if it is going to be different, it has to understand it is going to have, probably, multiple missions and its client basis probably everybody else except the Department of Defense.

What would this group look like if we were to sit down as to hammer out a mission statement or statements and to design a framework so that we can start looking at how to develop policy or what to do within that framework?

Mr. Fernandez, you said, you know, there are a lot of stove pipes and how do you—I don't know if you avoid it, but if—you know, how do you create the system that would integrate them all so that they—there is some synergy there, and without having to wait for shame or fear to drive us, and then—because that will—only ends up scapegoating somebody or some country or some form of some other thing, which has been the history of this country and not waiting for the gathering storm but looking for the silver lining that we can move towards or the pot of gold at the end of the rainbow.

Anybody can answer that.

Dr. FERNANDEZ. I think DARPA ARPA–E would sure be some kind of an experiment. I mean, it is not clear it is going to work in the Energy Department. You do your best to see what is going to happen. I think the most important thing, as was mentioned by several of the Members, is you have got to identify some initial focus for this entrepreneurial agency to work on. If you say work on all of energy, that is such a vast problem, I think ARPA–E is dead in the water. DARPA started with space. Space was the major—in particular, we were having to do with space surveillance.

Mr. HONDA. Okay.

Dr. FERNANDEZ. Okay. A particular problem to be able to look into other people's back yards when they could shoot down your airplanes. That was a very, very big deal, and it was very hard, and we didn't know how to do it. And the Soviets showed they could do it first and everything else. I think, for example—as—an example that might be considered would be, say, energy for transportation. That is subset, because it requires mobile capability, and the things that we do now, the things that we use gasoline for and oil for. Okay. And I am not saying that should be it, but one area like that that you can say, "Now you tell me how we are going to be independent in that area for the next 30 years and what is the technology that is high-risk, and who are the people we have got to get together some place to do it?" And then if it worked there, I think it would morph. As the energy environment changed, it would change with the energy environment. That is the essence of DARPA, which has been allotted to exist.

That is the only thing, I guess.

Mr. HONDA. I think you said health.

Dr. COTELL. Let me make a couple of comments.

First of all, I would praise the CIA, because the CIA actually formed In-Q-Tel two years before 9/11, and so I don't think you need a Sputnik. I think everybody here says something needs to be changed. Let us just figure out exactly how and how to structure it properly. It was that they weren't getting access to new information technology that was being developed in small start-up companies, because those companies don't target the government. It is way too hard to figure out how to sell to the government. Government wants to put their fingers in your intellectual property, and there are a whole bunch of barriers.

So the CIA looked at that problem and they said, "How do we solve it?" And they said, "Well, who do these companies work with?" They work with their venture capitalists. And so you pro-

vide funding, you are an investor, and you get a bit of mindshare into developing those products that ultimately the customer needs.

And sort of in the same way that DARPA changed over time from its original focus on space, In-Q-Tel no longer focuses exclusively on information technology. We have expanded the model, because, as an experiment, we showed that it worked, and we have expanded that model to include other technology areas. So we work in sensors now. We work in more hardware-oriented things in addition to the software-oriented things.

So again, I go back to my comment that if you are going to do this, identify the problem that you are trying to solve, set it up in such a way that you believe there is a reasonable expectation of success, make sure you have a long-term commitment to the experiment, and allow the experiment to morph over time and improve as it shows success.

Mr. HONDA. Mr. Chairman, I know my light turned red, but so far, what I have been hearing, it still feels like the old—the same old paradigm. And someone said think out of the box. Is that really thinking out of the box, or is it thinking within the box?

It is a question to all of you.

Chairman BOEHLERT. Dr. Mowery, you haven't had your go at this one.

Dr. MOWERY. Well, I think that, again, a mission statement is very difficult, in many cases, to translate into something operational. I think there are a lot of mission statements around for the energy area. There have been a number of commissions. And I think there is a mission statement implicit in the mandate for ARPA–E about reducing dependence by 20 percent on foreign energy sources, I think. Anyway, the point is, I think that it is translating it into something that is operational. That becomes extremely difficult and also adapting and ensuring a mission statement doesn't become a set of manacle that work against the flexibility that is needed in the energy R&D area.

So I think a mission statement, alone, may be necessary, but it is far short of what is necessary—or to catalyze energy R&D in the way we need to do it.

Chairman BOEHLERT. Thank you.

The gentleman's time has expired.

Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman.

There has been a lot of discussion here about funding and importance of funding. For any new and innovative alternative energy, you have got to have funding, and when you recommend something like that, you have got to pay for it.

Ms. Kenderdine, in your testimony before the Committee today, you mentioned that there should be some separate funding mechanism for ARPA–E. And with my thanks to you and your associate on advice for the last four or five years as we passed the Ultra Deep legislation that is in the energy bill that the President is considering right now of zeroing out, and I am going to be with him at 2:30 this afternoon to try and talk him out of it. But you have some suggestions, don't you, about how that funding could be? And keep in mind that Scott Tinker, the very brilliant writer from the University of Texas, that his paper had indicated that for this pro-

gram would be not costly to the taxpayers, because it is going to reap energy sources of its own source until we just can't get up from the depths.

But it is your recollection that his paper indicated that for the—for a $10 billion outlay, they get $12 billion back. Is that—am I thinking about his testimony?

Ms. KENDERDINE. Their analysis that they did was that it would return to the Treasury five times the amount of revenues that it cost in additional royalties that were produced from additional production on public lands. The—if I may, for a minute, the—I have spent a lot of time trying to figure out how to get programs paid for. Applied——

Mr. HALL. Could royalties from the program be used to support the ARPA–E trust fund to help develop some sustainable energy resources? Could that be used?

Ms. KENDERDINE. The—yes, sir, it could if the Congress directed that it be done. The—I—there are time scales that were focused on here, and everyone is talking about 30 years out. A lot of the panelists have talked about a transformational research that will take us to energy sustainability in 30 years. There is a significant amount of work that needs to be done in the interim. And I would also say there is a significant amount of energy in the world. A lot of it is in the wrong places. And so in the United States, I think it is going to be very difficult to get off of foreign oil. Our—there is no way to identify foreign oil in a world marketplace. I think we do need to invest in the technologies to produce as much domestic oil as we can to cover the interim period as we transition. I think we need to have concurrent efforts, kind of a near to mid-term time scales, long-term time scales. I would hope that an ARPA–E could cover that.

There is a significant amount of natural gas in the United States. It is technically recoverable. We have 60 years of technically-recoverable supply, but it is not—we need technologies to develop it. We are embarking on a course where we are going to be importing our natural gas from the same places that we are importing our oil from.

Having said that, the applied energy research requires significant industry input and industry leadership. It is very difficult to get the necessary industry input and leadership to do applied energy R&D without assured funding. And the trust fund that Mr. Hall established provides the industry the assured funding that it needs in order to invest its own assets in developing new technologies. As Mr. Hall said, it could generate a lot of additional revenues, and I am always on the lookout for new revenues and ways that we can fund energy R&D and with the objectives of ARPA–E which is sustainable, and so I think it is a—royalties are a good place to look.

Mr. HALL. Well, could the royalties from that program be used to support an ARPA–E trust fund to help develop these——

Ms. KENDERDINE. Yes, it could.

Mr. HALL.—sustainable?

Ms. KENDERDINE. Yes, it could, according to——

Mr. HALL. And without stating exactly how much over a period of time it would bring, I recommend people read Scott Tinker, I be-

lieve is his name, Bureau of Economy Geology at the University of Texas. And I think that is the team that played Southern California a couple or three weeks ago. I don't remember exactly how that came out, but I think that you will find that article very well written, and it points out a way to get energy for this generation of youngsters to where they don't have to fight a war overseas. And that is what energy does.

So you do believe that that could be used for that, and there is that five times the federal output? They put up the money but they get it paid back by known reserves that are there that are in the base of the Gulf that we can find, but we can't get them up? And with this view, with the universities helping us, Southern Cal, Stanford, and all of the other really bright places, it can get that technology.

Chairman BOEHLERT. Thank you very much, Mr. Hall.

And the gentleman's time is expired.

Mr. Udall.

Mr. UDALL. Thank you, Mr. Chairman.

It is always a privilege to follow Judge Hall, the wisest and most experienced Member of the Congress Judge.

Thank you all for being here. This is a crucial topic. Judge Hall just put his finger on it when he talked about sending men and women in American uniforms overseas to protect oil supply lines. I don't think any of us want to be in that position in the future.

Dr. Chu, if I could just direct a question to you. I do—before I do, I want to just make it clear to the Committee and all of those assembled that Mr. Gordon has, I think, an excellent piece of legislation I am proud to co-sponsor, and the concept of an ARPA–E really makes great sense.

But I would like to understand how it would fit into the Department of Energy's current renewable energy research. And specifically, Doctor, I think it is probably no surprise I am a strong supporter of the National Renewable Energy Laboratory, which is based in Colorado. And I am curious to what you would think about the role that ARPA–E would play. Would it complement NREL, or do you think there is—potentially would be at odds with each other?

Dr. CHU. I think, to be fair, I—we hope that it would complement it, but complement always means some necessary—some overlap, so there might a competition at the fringes. And let me give you a good example. NREL is working very hard to produce more efficient solar cells using existing semiconductor technology. The type of work that I see ARPA–E is funding is something that is very, very different than that: take advantage of completely new technology that is just emerging today. Many of those technologies that are emerging today are actually emerging in the basic science laboratories, new ways in making totally new nanomaterials. And so that is why I specifically said that that would be an example where it is more out of the box. The—they are working—NREL is working on enzymes and is actually collaborating with DuPont to work on enzymes to help break down cellulose. But the—there is a new field, called synthetic biology, which is a continuation of recombinant DNA, but instead of one gene, you put in dozens. But once you put in dozens of genes, the organism usually just breaks down.

But—and so the example I cited, given this new anti-malarial drug, is an example where one has figured out how to put in dozens of genes to produce a drug very inexpensively. It is a very total out of the box way of doing things. And that scientist, actually, who was working on that was going to go and solve another disease, and he is now convinced that he wants to use that talent to work on energy.

So it—that is again something where if the home of ARPA–E is closer to the basic research, you can get—it is better to get those really new ideas out into the marketplace and into innovation and into industry faster.

I just want to make one comment regarding the other question.

I was just thinking. Dr. Fernandez made an excellent suggestion about having the focus, like on transportation. And I think the American public might go for a few pennies. I am not sure how many billions of gallons of gasoline we use a year, but it—we are talking now, it could be less than a penny, it could be a few pennies that goes directly into looking at improving transportation and an alternative to oil. That part of it, and you know, the American public might buy that. I don't know.

Mr. UDALL. Doctor, thank you.

If I could now direct a question to the panel.

The *Energy Policy Act* authorized the Energy Efficiency and Renewable Energy funding levels at a much higher level than we have actually appropriated to those levels, and I know you can't speak for the DOE, but do you believe that there would be efficient—or sufficient resources, I should say, to continue EERE funding levels and support ARPA–E at the same time? And then to follow on, what do you think the appropriate levels for ARPA–E, when it comes to funding, would be?

Maybe we will start over here with Dr. Cotell.

Dr. COTELL. I have to say, I am completely unqualified to address that question at all. I am sorry to say, but it is just not my field, and I wouldn't want to express an opinion.

Mr. UDALL. Well, if you would like to weigh in later, for the record, you feel free to do so.

Dr. COTELL. Thank you.

Mr. UDALL. Dr. Fernandez, do you have any thoughts on this question?

Dr. FERNANDEZ. The only thoughts I have are my experience at DARPA.

A program—a DARPA program, to be meaningful, has an impact, runs between $10 to $30 million a year, so that if DARPA was going to have a half a dozen programs or ten programs, that would kind of set the yearly budget that you would have to have for DARPA. A lot of agencies, what they do, is they wallpaper every particular area by under funding, but they have got view graph level capabilities, so they are in everything but nothing is critically funded. And I think in any one of these areas where you are limited and you are trying to do these things, somewhere—like that number. And then if you picked the number of projects, that would tell you kind of what the number happens that you need. And I think you need a half a dozen or ten projects, because you don't want to bet the farm on a single project, high-risk kind of a thing.

So I think that is the kind of—where you make up an initial budget.

Mr. UDALL. Mr. Chairman, do you think we can get a short answer from the other two panelists?

Ms. KENDERDINE. Mr. Udall, the—I think you might have come in after I said that I think that energy R&D is dramatically under funded, I think, in a lot of areas. And that is—it has always been distressing to me. You might have been in Keystone when I had a concern—expressed concern over the outrage over the high price tag for the energy bill, which is $3 billion a year for 10 years, which , you know, depending—regardless of how you spend it, that is not very much money to be spending on our energy and national security future. So I would advocate funding at all authorized levels. I also think that a billion dollars a year, as recommended by the Academy, in new money so that it doesn't impinge on the funding for existing programs is—I would defer to their expertise in that—in what—how they came up with that funding amount.

Mr. UDALL. Doctor, any final thoughts?

Dr. MOWERY. I am not very expert. I will simply suggest that I agree that clearly alternative energy R&D has been under funded. I think, however, that an ARPA–E may not be the best vehicle for expanding funding of that, particularly by comparison with what I will suggest maybe an equally unrealistic alternative of more intervention on the demand side, you know, creating incentives for adoption.

Chairman BOEHLERT. Thank you very much.

The gentleman's time has expired.

Mr. Gutknecht.

Mr. GUTKNECHT. Well, thank you, Mr. Chairman.

I do think this is a very important hearing, and I want to thank all of you for coming here today. I must confess, first of all, my own prejudice. I have been a big supporter of DARPA, and I have seen some amazing things, and I happen to believe that success leaves clues. And frankly, when you look at how much we spend every month, I think the last number that I have in the month of August, we spent just south of $24 billion to buy oil from countries that don't particularly like us. So if you divide that up, we are approaching a billion dollars a day to buy oil from countries, as I said, that don't particularly like us. And I think the United States is ready to move forward.

I like the ARPA–E model, and I like it for a whole lot of reasons. And I am a big supporter of NREL. I have been out there, and I appreciate the work that they do. And frankly, I—one of the things we had a discussion about earlier today with one of the Administration officials, it is—one of the things that we have allowed to happen, unfortunately, on our watch is too much earmarking of monies that are intended to go to labs, like NREL, that are diverted to projects in people's district, and which is why I think that the DARPA model makes sense. And I think we have to protect research dollars at every level. I think we ought to let scientists, more or less, make those kinds of decisions.

But you know, I know there are a lot of questions, well, can we do this, can we do that, and—but I like to quote one of my favorite scientists who works for a little company in Minnesota called 3M.

Now he probably wasn't the first one to say it, but he is the first one I have heard it from. He said, "If we knew what we were doing, it wouldn't be research." And I think there is a certain element of that in all of this. And which is also why I like the ARPA–E model, and that is that there is an element of serendipity to research. Sometimes you start out looking for one thing and you stumble on to something, and you say, "Oh, my gosh. This could be very helpful."

But the other reason I want to make the case for ARPA–E is on one occasion, I actually took some business people—I sort of hosted my own trade mission out to NREL to take a look and discuss with some of the scientists out there what they are up to and compare notes with what some of the folks in the private sector are up to. On the way home, I remember talking to one of the businessmen, who was working on some, what I think, pretty interesting technologies in the State of Minnesota. And he seems to be making progress a lot faster.

For—let me give you an example. One of the things I have been interested that NREL is doing is the ability to take energy, when you have excess energy coming from these wind turbines, and we have a lot of wind turbines in southern Minnesota in my district. And amazingly, they are twice as efficient as the ones we were building five years ago. It has been an amazing thing to watch. But the problem is we don't have the transmission capacity. When the wind is blowing at 25 miles an hour, we can't—you literally have to shut them down, because we can't transmit the power. And the idea of using hydrogen as batteries, and they have had this and they have been working on this out in Colorado for a long time, what would look like—we call them harvest stores back in my part of the world where you actually store the excess electricity in the form of hydrogen when the wind is blowing hard, and then you reconvert it. And the only byproduct you get is completely pure water, which, out in southwest Minnesota, is a fairly valuable commodity as well.

But they have been working on this technology now for five years, and it is still not in the marketplace. And I asked one of the entrepreneurs. I said, "Why is it that you guys in the private labs seem to make progress faster than sometimes we see in the government labs?" And he smiled and he said, "Because we only eat what we kill."

And so the ARPA–E model really intrigues me, because in some respects, you are working with private entrepreneurs, and on, sometimes, very cutting-edge technologies. And as I say, when you look at the track record of DARPA, I mean, I think it is a track record we all ought to be proud of. Now have there been failures? Well, absolutely. I think any time you are funding any kind of research that is cutting-edge, you are going to have some of these things that just aren't going to work out. And I think we have to be big enough on this committee and in Congress to admit that.

But I do hope you will all give this concept and idea—or this idea an opportunity to be flushed out, because I think, long-term, when we are spending the kind of money that we are spending right now on energy, to import it from countries that don't like us, I do think America is ready for us to do some things. And the first of which

is not earmark the money that we do spend on research, to let the scientists make those decisions, but more importantly, create a way that we can—and the model that I like is that DARPA calls themselves—one of the DARPA people told me, like a big venture capital company that literally helps some of these small guys with great ideas to find out whether they really work or not. And if only a handful of them work out, I think I agree with the Judge from Texas. I think the return to the taxpayers could be really astronomical.

And I—if you want to respond to that, you are more than welcome to, but I—this is an issue I think, as Victor Hugo said, "This is an idea whose time has come."

Chairman BOEHLERT. I thank you.

Here—I will have one last question, and then I will recognize Mr. Gordon, and then I would ask all of our witnesses to expect—we will have a couple of more questions we will submit to you in writing, and we would appreciate a timely response, knowing the many demands on your time.

But the advisory panel, *"Rising Above the Gathering Storm,"* concluded that the biggest problem was basic research rather than later they support. And I am wondering, Dr. Chu, how the panel arrived at that analysis. And then I would ask all of the panelists if you would tell us where in the research sector do you see the biggest barriers to do—developing new energy technologies?

So let us start with you, Dr. Chu.

Dr. CHU. Well, we talked before about what I would consider applied research going to the next stage. Nuclear is a good example of that. The key is research, but it—a path is charted. And so we are really looking to ARPA–E to bring the fruits of the newest areas in science, like nanotechnology and synthetic biology, which haven't even been around long enough so that most venture capitalists know about it. So it really is in the spirit of a large venture capital firm making small investments.

Chairman BOEHLERT. Could I go right down the panel?

Dr. Mowery, would you have some comments?

Dr. MOWERY. Well, I think the big picture premise for the *"Gathering Storm"* document on the balance of the U.S. research portfolio is a reaction to the dramatic increases in biomedical R&D over the past 20 years relative to physical sciences R&D, and I think there is a—that is one of two issues that they respond to in suggesting energy, in particular, as a focus for increased basic research.

Again, I think if one is—the issue here, in some respects, is whether the priority is—if the priority is the health of the R&D system, which is an important issue, then I think basic research, particularly in physical sciences and engineering, and probably with a heavy tilt toward universities, is a very important priority.

If the priority is affecting energy consumption patterns, along the lines that we have discussed here this morning, then I think the demand side, again, really has to play an important role, because the near-term payoffs, and I am talking five years to that—to an intervention there are likely to be much greater than those associated with expanded fundamental research. In the nature of the fundamental research investment, it takes a long time to pay off, as Dr. Chu has suggested.

Ms. KENDERDINE. Mr. Chairman, I think there are kind of three areas where the barriers are substantial. The very near-term, where you have, as you mentioned technologies on the shelf that are sitting there and pushing them into the marketplace is very difficult. And that goes to your point. You really need market conditioning based on policy as much as you need research. You do need some very near-term research and pushes. We have an aversion to picking winners at that stage in the process, and so there is a lot of disincentives to doing that.

On the—in the long-term, I understand the support for basic research. I don't read ARPA–E as a pure basic research program, because basic research doesn't care about pushing products or developing specific technologies. That is not what basic research is about. It is unfettered. And if you look at the DARPA budget, the breakdown of their budget, the largest amount is for applied; it is not for basic. So they contemplate applied research functions in DARPA as well.

But I think that there is an enormous disconnect between the language that the basic researchers speak, between the language the applied researchers speak, and between the marketplace, and that is kind of the function I see for ARPA–E. And I think that that would help break down that barrier.

And I can't remember what my third one was.

Chairman BOEHLERT. Okay.

Dr. Fernandez, you were talking about DARPA, and that is referenced a lot. It is In-Q-Tel that is more like the venture capital operation. It isn't DARPA. Would you care to comment on that? I mean, you are——

Dr. FERNANDEZ. DARPA is not a venture capital firm.

Chairman BOEHLERT. No, no, I understand that.

Dr. FERNANDEZ. DARPA is more like an angel funding place, okay. Venture capitalists will not fund things where there is not a pretty good market already established. Okay. And DARPA funds things where the idea is that if you are lucky, what you end up creating will make a market. That is what DARPA is all about.

Most importantly, and I think this is one—I am not sure it is the purview of this committee, one of the things DARPA forces in its process is interaction between engineers and scientists, constant, and force that through building a device, building something as the output of the project. Scientists, a lot of times, are bent on discovering new phenomena and on understanding phenomena. It turns out that understanding is very, very hard to get across to a non-scientific person. Engineers build things. And we force everybody who works for DARPA to build something at the end to show what difference could it make. Now whether it gets adapted or not by DARPA is another story, all right. But that is a tradition at DARPA that came back from the Manhattan Project. The same people, these same ideas that scientists will build things. And that is how we communicate with the commercial sector. And——

Chairman BOEHLERT. Dr. Cotell, any commentary?

Dr. COTELL. Yeah, and some of my commentary I think is going to go back to my history as a research scientist and not a venture capitalist, and that is the observation that in the last few years, we have really reduced the budgets for basic research. And by basic

research, I mean those things that are looking at implementation five years or more out. And that is where I think you really want to make sure that the pipeline doesn't dry up. That is important. And what appeals to me about this concept of ARPA–E is that you would ensure funding for that kind of thing. And then, because it has been described as a nimble organization that is lean, there will be some selection as to which of those ideas you want to cultivate and pull in.

And I guess what I would say is, from the venture capital perspective, it would be very useful to inform that decision of which ones you want to pursue and continue with some market forces and market analysis, the kind of diligence that a venture capital firm would do in making that selection.

And so—and that is where I would really have that comment.

Now the one thing I would kind of disagree, perhaps, with Dr. Fernandez about is that sometimes it is not the same team that should be doing that entire spectrum of work. Sometimes you should have the basic research done by the brilliant scientists and transition it over time to more engineering-oriented people, either by collaboration or, you know, moving it out into a company. And I think that is another thing that I would like to see incorporated in this kind of organization is the ability to manage that, pull the right teams together to pursue things over time.

Chairman BOEHLERT. Thank you very much.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman, once again, for having this committee. I will be brief.

Thanks to the witnesses for coming today. I am sorry Mr. Gutknecht could not be here. I want to—I would like to concur with his very, I think, persuasive argument for ARPA–E.

You know, at some point, the American public is going to require the political leadership to step forward on this issue of—I think, a security issue of reducing our dependency on foreign energy sources.

Now unfortunately, when that kind of occurs, you don't just switch the switch. You have to have the basic research, the other type of research beforehand. I think that is why I—you know, ARPA–E gets that started. I know that the Majority, in trying to put this committee together, looked long and hard to try to find somebody who was against this proposal. The best they could do was find somebody that said, "Well, maybe we ought to do something." You know, "Maybe we should do more conservation." Well, certainly, we should do more conservation. Certainly, we should do more production. And this is a part of it, too. We need more of everything. And we are not going to be able to click that switch later unless we do this kind of work now.

I think it is time to—you know, to stop talking about all of the subtleties and get on with action.

So again, thank you all for being here.

Chairman BOEHLERT. And thank you.

I really appreciate it.

The hearing is adjourned.

[Whereupon, at 12:35 p.m., the Committee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Steven Chu, Director, Lawrence Berkeley National Laboratory

These responses are based my experiences as a member of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine's Committee on Prospering in the Global Economy of the 21st Century, chaired by Norman Augustine, that produced the report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* My responses to the questions below are as a representative of the Augustine Committee and not as a staff member of the Department of Energy.

Questions submitted by Chairman Sherwood L. Boehlert

Q1. How did the National Academy panel arrive at the recommended funding figures for ARPA–E? Is there an initial level of funding below which it would not be worth creating the agency? If so, what is that level and how did you determine it?

A1. Although the ultimate decision for funding ARPA–E would be the prerogative of Congress and the Administration, the Committee felt strongly that initial funding of at least $300 million was necessary to launch a significant program with real objectives. This should gradually increase over five years to $1 billion, at which point the program's effectiveness would be evaluated.

The budget amount is based on the Committee's review of the initial funding of other new federal research programs such as ARPA, ATP, In-Q-Tel, etc., and the degree to which they deemed it to be sufficient or not.

The report's budget estimate is a floor rather than a ceiling. To do less would be to risk funding only marginal advances and jeopardize the transformational goals of the program. Program managers need the flexibility that adequate resources provide to fund the most exciting scientific opportunities.

Q2. What role should universities, National laboratories, large companies and smaller companies play in carrying out ARPA–E projects? Should any of those categories of institutions be either required or forbidden to participate? How should participation be structured to simultaneously ensure that transformational research will be performed and that its results will be commercialized?

A2. The roles played by the organizations you list would depend on the particular scientific and technology needs of the particular project. There should be no barrier, nor any predetermined requirement for participation. The funding decisions should be made upon clear adherence to the principles outlined in the report. As I indicated in my testimony, ARPA–E should:

1. Bring a freshness, excitement, and sense of mission to energy research that will attract many of our best and brightest minds—those of experienced scientists and engineers, and, especially, those of students and young researchers, including those in the entrepreneurial world.
2. Focus on creative "out-of-the-box" transformational energy research that industry by itself cannot or will not support due to its high risk but where success would provide dramatic benefits for the Nation.
3. Utilize an ARPA-like organization that is flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programs that do not prove to be as promising as anticipated.
4. Create a new tool to bridge the gap between basic energy research, and development/industrial innovation.

The agency would itself perform no research, but would fund work conducted by universities, start-ups, established firms and national laboratories. Although the agency would be focused on energy issues, it is expected that its work (like that of DARPA or NIH) will have important spin-off benefits, including aiding in the education of the next generation of researchers.

Part of an ARPA–E program manager's responsibility will be the creation of appropriate and authorized consortia of laboratories, universities, and/or industry to ensure the dissemination and commercialization of new technologies. ARPA–E would begin to build a pathway for commercialization as soon as the technological objectives are within reach. How this is done should be left up to the Department of Energy to decide.

Q3. Why do you believe that the biggest gap in energy research is in the area of transformational, basic research? To what extent are there barriers later in the research process—during the prototype stage, or "the valley of death," or even finding funding later in the process? And to what extent did the National Academy panel consider recommending tools to stimulate demand for new technologies rather than just stimulating research on new ideas that may never find a market?

A3. The gap between basic science and technological advancement is often large and impossible to measure. However, research and development history has shown that significant leaps in technological development have occurred from the application of basic science to fundamental technological barriers when done in a focused and well-managed way. The Manhattan Project and the Apollo Projects are well-known U.S. examples.

An example I use often is of the development of the transistor at Bell Laboratories. Basic scientific problems had to be addressed using very basic science; however, Bell Labs had a very real and articulated objective. As science answered the questions and solved the problems, engineers and product developers saw the opportunities more clearly and began their work to capture the technology commercially. ARPA–E would mimic this process. There is no other analogous office within DOE that has responsibility for the cradle to grave aspect of shepherding transformational science to transformational technology.

The question of what is likely to have more impact, technological advances or policy pulls is an interesting one that is worthy of study. And, even within policy, there are many mechanisms which can be used whose effectiveness could be evaluated. The Committee focused on where it saw the largest gap and focused on technological advancements and included market considerations in the design of ARPA–E. The National Academies Committee on Science, Engineering, and Public Policy (COSEPUP), under whose aegis the *Rising Above the Gathering Storm* report was developed, is considering undertaking a study that would focus on the issue of the effectiveness of energy policy mechanisms.

Q4. What would be the pros and cons of Congress, in law, enumerating some of the general areas of research that an ARPA–E should focus on (i.e., an initial set of problems to solve, not a list of specific technologies)? Might this help prevent ARPA–E from gradually looking like every other Department of Energy (DOE) program?

A4. The Committee did not specifically address this issue, but I am happy to share my personal thoughts. The key to ARPA–E's success will be the quality of the program managers and the flexibility and freedom they are given to fund the science with the most exciting potential. Limiting the type of science or solution by listing them in legislation could prohibit funding on areas not even imagined now; however, focusing on a list of societal problems to be addressed may hold merit in terms of providing guidance to the program managers.

Q5. Why couldn't the National Academy's goals for ARPA–E be accomplished by reforming existing DOE programs by, for example, requiring the Office of Science (or even the National Science Foundation) to focus more of its research grants on energy problems? Or why couldn't DOE's applied programs focus on longer-range research?

A5. The Committee saw a gap between DOE's basic research and applied programs. It believes that each of these already has a full plate and adding more duties would not lead to the desired results for transformational research.

As I testified at the ARPA–E hearing, the establishment of an ARPA–E, or any program that intends the same results, should under no circumstances take monies away from the Department's basic science programs. If the Office of Science were more focused on particular energy problems, then its basic research program that might develop whole new ways of addressing energy questions might be damaged.

And, given the very specific way that the DOE applied energy programs is organized, it would be difficult to bring new transformational ideas that did not fit within one of the existing organizational boxes.

ARPA–E is needed to provide out-of-the-box transformational energy solutions that are challenging to achieve in DOE's current structure.

Q6. Can you give us a few examples of research that ARPA–E might pursue? Is any work being done in these areas now, and who is it funded by? Why couldn't any current funding agency carry out the ARPA–E agenda in that particular area?

A6. COSEPUP is considering undertaking a workshop that would address this issue, but, as was mentioned previously, any identification of a specific set of technologies is likely to limit the ability of ARPA–E to reach its goals. In my testimony, I provided the following examples of what ARPA–E might fund include:

1. **The development of a new class of solar cells.**

   Photovoltaic solar cells using semiconductor technology can be very efficient at converting sunlight into electrical energy, but the fabrication cost remains too high. Organic and polymer solar cells can be made at low cost, but the efficiencies are low and existing materials degrade in sunlight. One promising avenue towards inexpensive, efficient and long lasting solar cells is to create novel materials based on multiple elements that can be manufactured with thin-film technologies. Another approach is to create nano-particle devices (distributed junction solar cells) that use different nanostructures for the conversion of sunlight into charge carriers and for the collection of those charges onto electrodes.

2. **Biomass substitutes for oil.**

   The ethanol for transportation is currently produced from sugar cane, corn or other plants. However, the most cost effective bio-fuels will come from the conversion of cellulose into chemical fuel. When the fuel is burned, CO_2 is released into the atmosphere, but the overall cycle can, in principle, be carbon neutral. The creation of crops raised for energy will also take full advantage of our great agricultural capacity.

ARPA–E can fund the creation of new plants to be grown for energy by incorporating a number of genes introduced into plants. Recently, a team of scientists at Lawrence Berkeley National laboratory inserted many genes into bacteria to produce an extremely effective anti-malarial drug. The Gates Foundation has given this team a $42M grant to commercialize the technology so that the drug can be made available to the developing world. Similar technology can be used to make plants self-fertilizing, drought and pest resistant. Note that about 25 percent of the energy input in growing corn comes from fertilizer, which is made from ammonia derived from natural gas.

Research on more efficient conversion of cellulose into liquid fuel would also yield great dividends. Current methods use the high temperature/high acid processes that are very energy intensive. The breakdown of cellulose into ethanol is also accomplished with bacteria or fungi, but this process can be made much more efficient if the micro-organisms are modified with these methods.

Q7. To what extent could prizes be used to stimulate longer-range energy work and particularly work on integrating different scientific advances or technologies across fields? Could prizes ever be a substitute for an ARPA–E?

A7. The Committee recommended that the White House establish a Presidential Innovation Award and certainly one of these could be directed toward energy. It is unlikely, however, that such a prize would have the impact ARPA–E would have given it is providing the funding for research while the prize mechanisms only provides funding once the goal is achieved. Most researchers are unlikely to have the ability to fund research themselves. It is certainly possible, however, that a company could use the results of ARPA–E funded research to develop technological solutions.

Questions submitted by Representative Bart Gordon

Q1. What do you consider to be the most pressing challenge we face in energy? Will the cumulative efforts of our current federal civilian, university and industrial R&D infrastructure give us a solution(s) to that challenge?

A1. The Committee did not address this issue, but the National Commission on Energy Policy in its December 2004 report *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges* provides a good starting point. The commission recommended doubling the Nation's annual direct federal expenditures on "energy research, development, and demonstration" (ERD&D) to identify better technologies for energy supply and efficient end use. Improved technologies, the commission indicates, will make it easier to:

- Limit oil demand and reduce the fraction of it met from imports without incurring excessive economic or environmental costs.
- Improve urban air quality while meeting growing demand for automobiles.

- Use abundant U.S. and world coal resources without intolerable impacts on regional air quality and acid rain.
- Expand the use of nuclear energy while reducing related risks of accidents, sabotage, and proliferation.
- Sustain and expand economic prosperity where it already exists—and achieve it elsewhere—without intolerable climatic disruption from greenhouse-gas emissions.

I do believe that our current research infrastructure has the intellectual capital to address these challenges; it just needs the funded to do so.

Q2. If you were the Director of ARPA–E what three potentially transformational technologies would you be likely to pursue?

A2. Please see response to Chairman Boehlert's question number 6.

Q3. To your knowledge, is the current organizational structure of the Department of Energy and its various programs conducive to generating truly transformational energy technologies? Where is it lacking?

A3. Please see response to Chairman Boehlert's question number 5.

Q4. Do you believe that a DARPA-like program for energy can attract industrial interest sufficient to bring about real change in the energy technology sector? What are the barriers for industrial participation?

A4. I do believe that there will be sufficient industrial participation—perhaps from companies that are not the traditional ones focused on energy research. This will help lead to transformational solutions as new intellectual capital becomes part of the energy research enterprise.

The key barrier for industrial participation are likely to be issues related to intellectual property, but these can be addressed as they have for DARPA which has produced many commercial and government spinoffs.

Q5. To the extent that you are familiar with the energy research conducted in the Department of Defense, do you see potential linkages between any current research activities at DARPA and the research that would be conducted through ARPA–E?

A5. I lack sufficient knowledge regarding DARPA to answer this question.

Questions submitted by Representative Eddie Bernice Johnson

Q1. How do you feel about Mr. Gordon's legislation, H.R. 4435, establishing an ARPA–E?

A1. The National Academies does not endorse legislation.

Q2. What is your opinion about how an ARPA–E would be organized? Would the director report to the head of DOE's Office of Science or directly to the Secretary of Energy?

A2. ARPA–E would report to the DOE's Under Secretary for Science.

ANSWERS TO POST-HEARING QUESTIONS

Responses by David C. Mowery, William A. & Betty H. Hasler Professor of New Enterprise Development, Haas School of Business, University of California at Berkeley

Questions submitted by Chairman Sherwood L. Boehlert

Q1. You suggest in your testimony focusing existing basic research programs on energy programs and perhaps funding university centers devoted to energy questions. What could be done to increase the chances that ideas coming out of such centers were commercialized? How should one involve industry in a way that would not make the research less risky?

A1. I believe that expanded funding for university-based research on energy-related issues will enhance the progress of fundamental knowledge on a number of current and future solutions to energy-related challenges. In addition, of course, university-based research contributes to the training of future generations of the scientists and engineers who will address these challenges in energy and related areas. Such research might also address issues of policy design (e.g., emissions-trading schemes) to encourage greater conservation of energy from existing sources, as well as the development of new policies to encourage more rapid and effective implementation of technological solutions to these energy challenges.

Commercialization of the results of such research, in my view, is less a question of designing new "technology transfer" mechanisms than one of developing a set of market-based incentives for industry to invest in the debugging and market introduction of technologies based on advances in fundamental knowledge. Indeed, many potential technological solutions that could reduce climate-affecting emissions or enhance energy efficiency exist in prototype form, but do not face commercially attractive markets because of current policies that have stunted the development of such markets. Congress and the Executive Branch have created a diverse array of mechanisms to support university-industry technology transfer since the 1980s, and I believe that effective management of existing tools, rather than the creation of additional tools, is the best way to maintain the effectiveness of technology transfer activities.

The appropriate balance of risk in any such research programs is an important issue. Most university faculty, especially in fields such as engineering, pursue a mix of fundamental and applied research, but are professionally rewarded for work that is perceived by peers to be a significant contribution to knowledge. As a result, faculty have strong incentives to pursue high-impact research that may not be supported by industrial firms from their internal resources. Given these strong professional incentives, history suggests that a mix of funding sources (industry and public) can contribute to high-risk research with potentially significant impacts on knowledge and practice, while also enabling industrial firms to acquire sufficient familiarity with technological options to support their commercialization within industry.

Q2. Where do you believe the biggest barriers are in the energy research "pipeline"? To what extent are there barriers later in the research process—during the prototype stage, or "the valley of death," or even finding funding later in the process? Are the barriers you see better removed by tools that would stimulate the supply of new technologies or demand for new technologies or some combination?

A2. Although the energy R&D "pipeline" includes a number of phases that require the investment of substantial sums in high-risk projects, I believe that the lack of incentives for commercialization and adoption are the most significant barriers to commercialization of technological innovations that can contribute in the near-term to solutions to energy-related challenges. The United States has a financial system that is extremely innovative in developing solutions to risky investment prospects. The biggest problem in the energy field, in my view, is not the fact that the risks of technology development and commercialization are too high.

The most important barrier to the commercialization of more efficient, lower-emission technologies is the perception that the market for such technologies is too small and/or uncertain to support the large investments that would be necessary to promote their commercialization. In other words, the most important barriers are those at the very end of the "pipeline," in the marketplace.

Q3. What would be the pros and cons of Congress, in law, enumerating some of the general areas of research that an ARPA–E should focus on (i.e., an initial set of problems to solve, not a list of specific technologies)? Might this help prevent

ARPA–E from gradually looking like every other Department of Energy (DOE) program?

A3. I believe that Congress should oversee the strategy, operations, performance, and finances of an ARPA–E, but avoid involvement in defining the agency's research agenda. Congress is not well-positioned to provide detailed guidance on the specific technological areas that an ARPA–E should pursue, and Congress historically has not micro-managed the R&D agenda for DARPA. A strong advisory board of independent experts drawn from federal laboratories, industry, and academia should provide guidance and oversight of the ARPA–E R&D agenda. Keeping in mind that DARPA benefited from strong links with its "customers," the armed services, one of the most important roles of such an advisory board is representing the views and needs of the major "customers" for ARPA–E R&D in both the industrial and user communities.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Melanie Kenderdine, Vice President, Washington Operations, Gas Technology Institute

Questions submitted by Chairman Sherwood L. Boehlert

Q1. What role should universities, National laboratories, large companies and smaller companies play in carrying out ARPA–E projects? Should any of those categories of institutions be either required or forbidden to participate? How should participation be structured to simultaneously ensure that transformational research will be performed and that its results will be commercialized?

A1. It is my understanding that DARPA program managers are given a great deal of discretion over project funding; presumably this is one aspect of the DARPA program that would be replicated in an ARPA–E. ARPA–E project managers are empowered to select projects and make investments on merit, regardless of which institutions submit proposals. Because the customers for ARPA–E projects are, by and large, energy end users in the private sector, however, care should be given for proper vetting of activities with requisite technical advisory committees and peer review organizations, with the understanding that peer review for applied research necessarily entails different players than for basic research.

Q2. Why do you believe that the biggest gap in energy research is in the area of transformational, basic research? To what extent are there barriers later in the research process—during the prototype stage, or "the valley of death," or even finding funding later in the process? And to what extent did the National Academy panel consider recommending tools to stimulate demand for new technologies rather than just stimulating research on new ideas that may never find a market?

A2. I cannot speak to the National Academy's considerations. I do not necessarily agree that the biggest gap in energy research is in "transformational, basic research" and I do not believe that research must be basic to be "transformational." As I noted in my written testimony, there was confusion in the report relative to the NAS program description,

> "These descriptions beg several questions. Is ARPA–E primarily a basic research program, an applied research program, a program to "turn cutting edge science and engineering into technology," an effort to accelerate commercialization, or all of the above? Each of these suggests different leadership, organizational structures, personnel capabilities, and reporting chains, as does a single program that contemplates performing *all* these functions (an approximation of DARPA). A clarification of program objectives will drive the research management model and is fundamental to program success. Further, there needs to be a clear delineation between DOE's existing basic and/or applied research programs and ARPA–E's mission, research targets, reporting chain, etc."

Further, I agree that there are significant barriers at later stages of research, and noted in my written testimony (assuming program objectives are clarified), "that at DOE an ARPA–E that is focused primarily on applied R&D (or includes a substantial applied R&D component) would typically require industry cost share (which is not the case at DARPA). Federal procurement, intellectual property, contract management provisions, DOE orders and other federal requirements are off-putting to many industry players, placing de facto barriers to industry participation and cost share commitments—essential elements to successful applied energy R&D, including demonstration, deployment and technology transfer.

Federal energy R&D is performed under the constraints of annual appropriations which are inconsistent from year-to-year, administration-to-administration and secretary-to-secretary. Also, program funds are largely "mortgaged" from the start, and increasingly line-itemed. The risks and limitations of the funding process further discourage industry participation and its commitment of matching funds, making it more difficult to optimize the migration of technologies into the marketplace."

Q3. What would be the pros and cons of Congress, in law, enumerating some of the general areas of research that an ARPA–E should focus on (i.e., an initial set of problems to solve, not a list of specific technologies)? Might this help prevent ARPA–E from gradually looking like every other Department of Energy (DOE) program?

A3. Congress could enumerate areas "including. . .." which might provide general policy direction without prescribing or limiting areas of research. General focus areas for ARPA–E could include:

- development of economically sustainable energy sources, which implies a reduction in oil consumption and U.S. reliance on imported energy from unstable regions of the world, and the development of domestic, hemispheric and alternative energy sources
- environmental mitigation, particularly greenhouse gas capture and sequestration,
- energy infrastructure development to produce, refine and distribute new sources of energy
- energy efficiency, with a focus on end use efficiencies.

These focus areas track those of other programs in the Department. In my view, an ARPA–E would provide the greatest value to DOE in its *structural* differences from other DOE energy programs, not necessarily in its focus areas (see Question 4).

Q4. Why couldn't the National Academy's goals for ARPA–E be accomplished by reforming existing DOE programs by, for example, requiring the Office of Science (or even the National Science Foundation) to focus more of its research grants on energy problems? Or why couldn't DOE's applied programs focus on longer-range research?

A4. I would first note that when DARPA was formed, it was not intended to supplant the research programs of the services and it does not function in this way. Rather it is designed to add additional capability to DOD that enables the—

- "Development of integrated concepts beyond the purview of a single service
- Taking on large-scale proof of concept demos with a scientific process and a willingness to fail
- Working with the OSD leadership to broker the commitment of the services."

An ARPA–E could provide similar capability at DOE. There are some gaps inherent in the structure of DOE programs:

- "DOE's applied research programs are organized around fuel sources, e.g., coal, oil, gas, nuclear, renewables (the efficiency program is an exception). The existing organizational structure and focus provides a solid foundation for the Department's applied research and the support of strong constituencies; it runs the risk however of isolating oil supply from transportation or fossil fuels from efficiency, for example, and promotes a tendency to focus on incremental or discrete technologies (exceptions are generally *within* programs, not *across* programs) as opposed to systems that integrate research needs from supply to distribution to end use.
- The organizational separation of DOE's basic energy research program from its applied research programs makes sense in many instances, but it also makes the migration of certain basic research *findings* to applied research *solutions* undisciplined, more difficult, and often, serendipitous.

There are both ad hoc and, in some instances, formal structures at DOE that encourage communication and coordination between the various applied research programs and between the applied research and basic research programs. In the final analysis, however, the competition for funding from the same appropriation, bureaucratic separation, and different program cultures and performance measures, ultimately work against optimum levels of cooperation and coordination across programs.

An ARPA–E like program could help fill these gaps and supplement but not supplant the missions of existing DOE programs. As noted earlier, the "development of integrated concepts beyond the purview of single service [program]," is one of the features of DARPA that is desirable for replication. To some extent, on certain key problems to be identified, an ARPA–E could provide the *formal integrating function* that fosters a portfolio approach to a problem. In addition, providing ARPA–E with *administrative flexibility* in contracting, hiring, etc., and the easy transfer of personnel and ideas between the government, industry and academia will further distinguish ARPA–E from existing DOE programs.

Finally, replicating DARPA's formal *extraction of value from the entire research continuum*—from basic to applied to development to deployment—would be largely unique to the DOE system (DARPA's budget reflects the research continuum includ-

ing basic and applied to large scale demonstration). Directing a minimum percentage of program funds to basic research—for both the national laboratories and universities—would protect against the tendency of DOE's energy R&D customer base comprised largely of industry to focus on near-term research and results. Congress might also consider setting aside a portion of ARPA's funds as venture capital for promising, innovative opportunities in the private sector.

In short, ARPA–E would be distinguished from existing DOE programs more by its structure than by the policy objectives its research would address. There is, however, a danger in a "structural" as opposed to policy-driver distinction; without an upfront, clear articulation of some fundamental strategic research thrusts, an ARPA–E could risk becoming an organization in search of a mission. Nevertheless, the drivers described above do not differ substantially from similar gaps DARPA seeks to fill—"research that the services are unlikely to support because it is risky, does not fit [the services] specific roles or missions, or challenges their existing systems or operational concepts."

Q5. Can you give us a few examples of research that ARPA–E might pursue? Is any work being done in these areas now, and who is it funded by? Why couldn't any current funding agency carry out the ARPA–E agenda in that particular area?

A5. I would not pre-judge the research an ARPA–E might perform and believe this should be left to the energy technologists, not those of us who reside in the energy technology policy space.

Questions submitted by Representative Bart Gordon

Q1. What do you consider to be the most pressing challenge we face in energy?

Will the cumulative efforts of our current federal civilian, university and industrial R&D infrastructure give us a solution(s) to that challenge?

A1. I believe the most pressing energy challenges we face are meeting global energy needs at the same time we reduce carbon emissions sufficient to avoid the most serious impacts of global warming, and; 2) the transition from fossil fuels to alternative fuels without significant economic dislocation.

Q2. If you were the Director of ARPA–E what three potentially transformational technologies would you be likely to pursue?

A2. For the mid-term, I would support a suite of technologies to promote the interchangeability of fossil fuels sufficient to utilize the same infrastructure for distribution and key end uses. Carbon capture and sequestration technology development is also critical. Finally, longer-term research in methane hydrates could dramatically enlarge the world's energy resource base.

Q3. To your knowledge, is the current organizational structure of the Department of Energy and its various programs conducive to generating truly transformational energy technologies?

Where is it lacking?

A3. DOE's applied research programs are organized around fuel sources, e.g., coal, oil, gas, nuclear, renewables (the efficiency program is an exception). The existing organizational structure and focus provides a solid foundation for the Department's applied research and the support of strong constituencies; it runs the risk however of isolating oil supply from transportation or fossil fuels from efficiency, for example, and promotes a tendency to focus on incremental or discrete technologies (exceptions are generally *within* programs, not *across* programs) as opposed to systems that integrate research needs from supply to distribution to end use.

The organizational separation of DOE's basic energy research program from its applied research programs makes sense in many instances, but it also makes the migration of certain basic research *findings* to applied research *solutions* undisciplined, more difficult, and often, serendipitous.

There are both ad hoc and, in some instances, formal structures at DOE that encourage communication and coordination between the various applied research programs and between the applied research and basic research programs. In the final analysis, however, the competition for funding from the same appropriation, bureaucratic separation, and different program cultures and performance measures, ultimately work against optimum levels of cooperation and coordination across programs. An ARPA–E like program could help fill these gaps and supplement but not supplant the missions of existing DOE programs.

Q4. Do you believe that a DARPA-like program for energy can attract industrial interest sufficient to bring about real change in the energy technology sector?

What are the barriers for industrial participation?

A4. At DOE, an ARPA–E that is focused primarily on applied R&D (or includes a substantial applied R&D component) would typically require industry cost share (which is not the case at DARPA). Federal procurement, intellectual property, contract management provisions, DOE orders and other federal requirements are offputting to many industry players, placing de facto barriers to industry participation and cost share commitments—essential elements to successful applied energy R&D, including demonstration, deployment and technology transfer.

Federal energy R&D is performed under the constraints of annual appropriations which are inconsistent from year-to-year, administration-to-administration and secretary-to-secretary. Also, program funds are largely "mortgaged" from the start, and increasingly line-itemed. The risks and limitations of the funding process further discourages industry participation and its commitment of matching funds, making it more difficult to optimize the migration of technologies into the marketplace. If ARPA–E is funded at relatively low levels in its early years, the ramp-up in the out years as contemplated in the NAS report would place that important increment (likely necessary when projects get to the demonstration phase, for example) in competition with other DOE programs as well as with programs in other agencies that are funded through the Energy and Water Appropriations Committee; this lack of certainty in outyear funding could further complicate and discourage longer-term industry commitments to critical projects.

Q5. To the extent that you are familiar with the energy research conducted in the Department of Defense, do you see potential linkages between any current research activities at DARPA and the research that would be conducted through ARPA–E?

A5. I am not familiar with specific energy research being done at DARPA.

Questions submitted by Representative Eddie Bernice Johnson

Q1. How do you feel about Mr. Gordon's legislation, H.R. 4435, establishing an ARPA–E?

A1. Mr. Gordon's legislation provides a welcome focus on a very important issue—how to appropriately organize transformational research and technology at the federal agency of primary jurisdiction. If properly organized, empowered, and funded, however, an ARPA–E type program could provide a new and aggressive link between the needs of the energy marketplace and research directions, operating as a primary interface between the energy industry and DOE's national laboratories and experts in academia.

Q2. What is your opinion about how an ARPA–E would be organized? Would the director report to the head of DOE's Office of Science or directly to the Secretary of Energy?

A2. The NAS recommends that the ARPA–E program director report to the Under Secretary of Science. The ARPA–E proposal represents a fairly significant departure from how DOE currently conducts business. It is bound to raise issues of coordination with existing programs, concerns about picking winners, and other potential oversight issues as the program breaks new and controversial ground.

These are sensitive issues both internally and externally and may require the imprimatur of the Secretary or Deputy Secretary whose portfolios are the broadest and authorities are sufficient to manage and mediate the controversies that could arise from such a fundamental change in approach to DOE research management. Also, the unique contractual, personnel and pay scales contemplated in an ARPA–E program may require greater organizational separation from existing programs (organizational independence is identified as a key positive feature of DARPA) than is possible in a reporting structure through the Under Secretary with line authority for other programs. From an organizational/reporting perspective, I believe it is essential to program success that the ARPA–E program director be a direct report to either the Secretary or Deputy Secretary.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Frank L. Fernandez, President, F.L. Fernandez, Inc.

In what follows, below, I have tried to provide you with answers to the questions that you posed. At the outset, I need to make sure that you understand that I am not an expert in the business of energy. As a result, I may miss some important points and for this I apologize, at the outset.

In answering the questions, I am assuming that in creating an ARPA–E the U.S. decided, as a matter of policy, that technological superiority is crucial to the energy security of the U.S. and that this superiority requires revolutionary, technically based innovation. Otherwise, there does not seem to be a need to do this.

In addition, let me further assume that, if created, ARPA–E would have a mission and resources somewhat similar to DARPA's. . .to create, demonstrate and transition high risk, high return technologies in order to maintain U.S. technological superiority in energy. Also, I assume that ARPA–E would have the necessary authorities to accomplish the mission, as I stated in my testimony.

Questions submitted by Chairman Sherwood L. Boehlert

Q1. You said at the hearing that DARPA could not be an exact analogue for ARPA–E, but that the DARPA model could be useful nonetheless. In what ways would an ARPA–E have to be different from DARPA?

A1. The common, most important lesson that I have learned in my various careers is that in order to successfully provide revolutionary, technically based innovation, there must be a balance of both "technology push" and "operational pull." This only comes about through the use of creative people who can bridge this gap. It is not just about financial or organizational resources.

If this is correct, I believe that the most important challenge would be that ARPA–E would need to attract senior technical professionals who understand both the "business of energy" and the technologies that will affect the future of energy superiority.

In the DOD, DARPA had access to very competent, technically trained, military officers and operationally oriented, technically trained DOD civilians in addition to people from the universities and laboratories. ARPA–E does not appear to have ready access to such a diverse pool of technical talent with operational backgrounds. From what I have been able to discern from published material, these kinds of people do not generally seem to reside in universities or the national laboratories. Finding and attracting these people in the other parts of the DOE will require very special recruiting authorities and capabilities within ARPA–E.

In addition, ARPA–E will need to recruit people with these dual skills from the relevant energy industries. This will probably require special arrangements to guarantee that the companies involved would have their important technical secrets protected, while at the same time providing the U.S. with the knowledge of the constraints that the "business of energy" places on the successful transition of technologies into the marketplace.

This is the most important difference that I believe exists between DARPA and ARPA–E. . .the possible lack of a ready pool of available professional talent in the DOE to link the technology to the user of the technology. This difference must be addressed at the outset if ARPA–E is to be successful.

Q2. You say about the examples in your testimony that they went first to the commercial sector, then to the military. But many experts on DARPA suggest that the promise of a military market has been a key to the success of DARPA projects. Certainly, many advances in computing and networking were put to work first in the military sector. And SEMATECH is an unusual example in that part of the impetus came from Congress to help a mature industry. How common has it been for DARPA projects to succeed commercially first and what might that indicate about how to set up an ARPA–E?

A2. In the world where the DOD makes the market, i.e., the actual war fighting systems, the promise of a military market has certainly helped DARPA, because the DOD could provide industry with a clear indication that there would, indeed, be an acquisition of a major new aircraft or missile system, for example. However, it has been shown time and time again, that unless there is a commercial use for most of the technologies involved in these systems, the DOD is forced to support the total cost of the manufacturing and maintenance infrastructure and ends up with a very

cost ineffective system. The Nation chooses to do this with technologies like stealth, but not with network technologies, for example.

What DARPA does for the majority of the technologies that it sponsors, which end up as having both military and commercial use, is to fund the maturation of the technology and the demonstration in a realistic operating environment, using the military. By funding this risky stage before there is a clear market need, DARPA helps to "make a market." This is the way that revolutionary innovation occurs, when it does.

ARPA–E does not, generally, have an acquisition partner in the DOE. As a result, I think that it will need to carefully pick its projects in selected areas where the DOE, as part of the Federal Government can provide the energy industry with something special, besides purely financial subsidies. These subsidies do not require an organization like ARPA–E.

This initial choice of focus areas for ARPA–E must be well thought out, in my opinion. DARPA had space, because of Sputnik. It did not, initially need to deal with all of the DOD technology issues. Space provided a problem that was both one of national importance and where technology based innovation was paramount.

As a thought experiment, suppose that ARPA–E initially focused on the energy needed for transportation in the U.S. A key issue here seems to be the need to reduce U.S. dependence on foreign, petroleum based fuels. Applicable technologies will include more efficient and multi-fuel vehicle propulsion design and possible non-petroleum based fuels.

My very rough estimate is that government owned and fueled vehicles (federal, state, local, military) represent about ten percent of the U.S. fuel consumed for transportation. This is a niche market that will use commercial suppliers but where the government could influence, mature and demonstrate technologies in a realistic environment and at a scale where the transition to non-government utilization could be realistically estimated.

ARPA–E could partner with DARPA and its access to military and civilian talent in the DOD for the military transportation. It could tap key, knowledgeable DOE talent in the Federal, State and local government subsidized transportation areas.

With this arrangement, ARPA–E could establish programs to look at technologies presently considered high risk but potentially high return for planned transportation platforms and for kits needed to back fit legacy platforms. Finally, it could do the same for the many alternative fuel sources being proposed in order to demonstrate scalable, environmentally acceptable, technologies to make these alternatives commercially viable.

The government vehicles could be the test market for these technologies and the military might even agree to long-term buys of the best performers. This would be a large, but manageable program and could form a good basis to test the hypothesis that an ARPA–E could add significant value to the DOE activity.

This is only one example and is certainly not well thought out, but might be used to initiate debate and thought.

Q3. You said in your testimony that DARPA has been more like an angel investor than a venture capitalist. Could you elaborate on what you mean by that and how it might apply to an ARPA–E?

A3. Angel investors are often individuals with detailed knowledge of particular industries and quite often will invest in start up companies with the potential for a new technology and no established business plan. Venture capitalists generally focus on supplying a market need, not necessarily on making a market.

Since DARPA works with many companies and individuals who have good ideas for technologies that can solve problems, even though the markets for these may not currently exist, I think that DARPA is more like an angel investor. DARPA is not driven by military requirements and current acquisition programs.

The major impact that this observation has on the construct of an ARPA–E is to make sure that, at the outset, it is understood, by all, that ARPA–E is not the organization to subsidize investments for known technologies and known markets. It must be the organization with the charter to try to leapfrog established technology development roadmaps. It must be allowed to back projects that fail because the technical reach is too far in return for the market maker program that is truly revolutionary.

Before I give my answer, I want to repeat my recommendation that if such an Agency is established, it be given a name more in line with its mission concerning the 21st century energy needs of the Nation.

Questions submitted by Representative Bart Gordon

Q1. What do you consider to be the most pressing challenge we face in energy? Will the cumulative efforts of our current federal civilian, university and industrial R&D infrastructure give us a solution(s) to that challenge?

A1. I feel that our most pressing challenge in energy is to see how much we can use technology to do away with our dependence on foreign sources of energy and, eventually, to transition to renewable, sources of energy.

In my opinion, the R&D in the federally funded Laboratories and Academia, while representing excellent science and potential innovation, does not link well with the evolutionary, low risk, product oriented work in the industrial sector. There is a large gap between discovering new science, demonstrating an invention using this discovery and fitting this invention into an established business model. Most revolutionary inventions do not do as well in established business models as the evolutionary developments, precisely because the evolutionary products are satisfying current and near-term business requirements.

To be successful, a revolutionary innovation requires someone who will bet their career on the seeing how the business model can be changed to accommodate this innovation (the entrepreneur) and someone in the particular industry sector who can protect and nurture this person and the project while the innovation is becoming a competitive way of doing business (the top cover).

ARPA–E can be the vehicle to fund, provide and connect these entrepreneurial persons to industry visionaries.

Q2. If you were the Director of ARPA–E, what three potentially transformational technologies would you be likely to pursue?

A2. As Director of ARPA–E, I think that I would, initially, focus on technologies to:

a. Reduce the cost of manufacturing the needed amounts of currently used transportation fuels (gasoline, diesel, aircraft fuel, etc.) from U.S. alternative energy sources vs. petroleum.

b. Build fission reactors with radioactive waste products whose lifetime is measured in hundreds of years vs. the many thousands of years in our current reactor waste, which makes safe disposal an impossible engineering problem.

c. Accelerate work going on in increasing the efficiency of cheap, newer, plastic solar cells for direct conversion of solar power to electricity.

Q3. To your knowledge, is the current organizational structure of the Department of Energy and its various programs conducive to generating truly transformational energy technologies?

Where is it lacking?

A3. The current organization generates an incredible array of new technologies that could be transformational but does not have an Agency whose charter, culture is to make "deals" with industry to fund the work needed to mature the technology and invent, adapt business practices to this new technology and where failure can occur for a variety of reasons.

Q4. Do you believe that a DARPA-like program for energy can attract industrial interest sufficient to bring about real change in the energy technology sector?

What are the barriers for industrial participation?

A4. Yes, a DARPA-like program could bring about real change in the energy business, but only if it, initially focuses on some particular subset of the problem. The energy problem is too be too be tackled by a DARPA like organization all at once. I suggest that the subset of fuel for transportation, near- and far-term, could be a good starting point. Here, technology for cost competitive, environmentally acceptable fuel manufacturing processes using non-petroleum domestic energy sources could be a natural area where there are many ideas but few with the level of technology readiness that would attract industry.

Q5. To the extent that you are familiar with the energy research conducted in the Department of Defense, do you see potential linkages between any current research activities at DARPA and the research that would be conducted through ARPA–E?

A5. I think that a major linkage between DARPA and ARPA–E could be the discovery, invention and development of technologies to allow for cost competitive man-

ufacturing of current transportation fuels from domestic sources, which is, currently, very important to the military and the Nation as a whole.

A joint program office could be staffed and funded by both agencies. The military services could agree to start and sustain a prototype market for the fuel and to test emerging cost savings technologies that resulted form the joint venture. The DOE could provide access to willing industrial sector people who would provide the non-petroleum energy sources, and who might eventually, create an industry funded consortium to maintain competitiveness against foreign fuel suppliers. This project could be very focused in space and time and would test the ARPA–E concept.

Questions submitted by Representative Eddie Bernice Johnson

Q1. How do you feel about Mr. Gordon's legislation, H.R. 4435, establishing an ARPA–E?

A1. The legislation proposed by Mr. Gordon is a good start but the difference in roles, missions between ARPA–E the Labs and Academia must be crystal clear or the result will be a turf battle for limited resources.

Q2. What is your opinion about how an ARPA–E would be organized? Would the director report to the head of DOE's Office of Science or directly to the Secretary of Energy?

A2. ARPA–E does not fit into the Office of Science. Its job is to use science to help create, demonstrate technologies and systems for the industrial sector to implement, as I said earlier in this note. In my opinion, ARPA–E must report to the Secretary of Energy to give it the "top cover" that it will need to be successful.

The culture of scientific, excellence and continuity required for a department of science is not consistent with the entrepreneurial culture needed to make an ARPA–E successful. As I said in my testimony:

Like DARPA, I think that ARPA–E should be the central energy research and development organization in the DOE and should have a clear, national purpose for its projects that differentiates it from the laboratories and other agencies. It should have visibility and access to the top management of the Department and not be part of an established R&D bureaucracy.

Like DARPA, I think that it should have a mandate to create, demonstrate and transition high risk, high return technologies to maintain U.S. technological superiority in energy.

Like DARPA, I think that it should be funding agency, with very little infrastructure, a flat organization and a small, very competent, entrepreneurial, technical staff. Budget and program control should rest with the Director and the program manager and the agency should enforce constant turnover of both programs and staff.

Like DARPA, it should have both the special authorities and the resources needed to exercise these authorities. For example, while flexible contracting and hiring authorities are necessary, implementing these authorities requires dedicated, in house, resources.

Unlike DARPA, however, ARPA–E will be in the energy business, not the defense business. I do not think that it should be a strict clone of a defense agency.

Instead, I think that ARPA–E should receive the funding, flexibility, leadership authorities and, most importantly, the time necessary to let it become the change agent for the DOE.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Catherine Cotell, Vice President for Strategy, University and Early Stage Investment, In-Q-Tel

Questions submitted by Chairman Sherwood L. Boehlert

Q1. Does In-Q-Tel support any technologies that are primarily energy technologies? If so, what are they and why are they useful to the intelligence community?

A1. Yes, In-Q-Tel has made investments in energy-related technologies. Many of In-Q-Tel's energy investments are motivated by an Intelligence Community partner problem set which has expressed a need for mobile power sources. Consumer electronics (cell phones and laptops, for example) are driving the development for the mass market of high energy, lightweight, small form factor, reliable power sources that do not require frequent recharging. In-Q-Tel supports the Intelligence Community's exposure to emerging commercial energy technology breakthroughs via its investments in companies aiming at the large consumer electronics market.

Examples of In-Q-Tel's investments in the energy sector include:

- Electro-Energy, Inc., Danbury, CT, with manufacturing facilities in Colorado Springs, CO (now publicly traded)—markets a novel, bipolar rechargeable battery design offering high energy density and high power density.
- Nextreme Thermal Solutions, Research Triangle Park, NC—develops and manufactures embedded thermoelectric components utilizing novel super lattice nanotechnology to operate as a power generator for converting heat to electricity.
- Qynergy, Albuquerque, NM—is a portable power solutions company, focusing on integrated hybrids of radioisotope-fueled energy cells, photo-voltaics, energy-harvesting systems and advanced lithium batteries.
- Skybuilt Power, Arlington, VA—sells a Mobile Power Station for rapid deployment of solar, wind, micro-hydro, and fuel-based power.

In addition to these companies in our portfolio, In-Q-Tel is actively evaluating other investment opportunities in the energy sector including companies offering technology products in the areas of fuel cells, active and passive solar energy, energy harvesting from non-traditional sources, and novel materials for power applications.

Q2. Is the venture capital market becoming more interested in energy technologies? Do you have a sense of whether the lack of venture capital is a significant barrier to commercializing new energy technologies? What indicators would one consult to determine that?

A2. The Venture Capital (VC) market certainly appears to be showing an increased interest in alternative energy. According to Clean Edge, a Portland, Oregon-based research firm and Nth Power, an energy tech venture firm based in San Francisco, U.S.-based venture capital firms invested $917 million in energy technologies in 2005, a 28 percent increase over 2004. This $917 million represented only 4.7 percent of all VC investments last year, but considering that six years ago, only one percent of all VC dollars were invested in energy technology, as observed by the past president of the National Venture Capital Association, Mark Heeson, VC investment in clean energy has gone from "a drop in the bucket, to a trickle in the bucket."

The availability of venture capital can be linked to innovation in almost any sector, including energy. Increasing the availability of capital to small firms focused on commercializing energy technologies, whether the capital comes from venture or government sources, would likely enhance innovation in the energy sector. From a venture perspective, the barriers to investment in alternatives to fossil fuels include the large size of the investments required relative to investment opportunities in other sectors, the long lead time to adoption, and the ready availability of inexpensive alternatives to many of the technologies.

Q3. What would be the key factors in making an energy version of In-Q-Tel a success? How could such an organization decide what to invest in since the criterion would presumably not be how useful a particular technology would be to the government? Are there any dangers in making the government a venture capitalist in what is essentially a civilian, commercial market in which the government's needs are not particularly different from anyone else's?

A3. A fundamental goal of In-Q-Tel is to accelerate the rate at which the CIA and the Intelligence Community can utilize emerging technologies in the interests of na-

tional security. In-Q-Tel's investment decisions are driven by the impact the technology will have on CIA and Intelligence Community performance and operations. In-Q-Tel uniquely uses the venture capital model to achieve this goal. As a strategic venture capital firm operating on behalf of the CIA and the Intelligence Community, In-Q-Tel invests in technologies that ordinary procurement processes would likely never discover. Moreover, even if they were discovered, government procurement processes would likely be so cumbersome as to discourage the small firms—who often spearhead the development of really new technologies—from cooperating with the government.

After more than six years of operations, In-Q-Tel has identified several elements for success of the model for the CIA and the Intelligence Community. These include strong support from the host organization; a close partnership structure with a group in the host organization tasked with assisting in problem definition and subsequent solution transfer; a good relationship with the procurement office at the host agency; shared expectations; a long-term financial commitment; focus on mission impact (more than financial return); emphasis on transferring solutions to end users and financial commitment from those users; and the ability to function in the venture community, exercising best business practices.

Underlying essentially all the elements for success named above is In-Q-Tel's understanding of the needs of the CIA and the Intelligence Community. In-Q-Tel derives that understanding from its relationship with the In-Q-Tel Interface Center (QIC), which is housed at the CIA and also serves as executive agent for In-Q-Tel's work with other elements of the Intelligence Community.

As I understand the objectives for DOE funding, there is consideration of using an In-Q-Tel model to spur the development of new energy technologies for the commercial market, not the government market. If that is the case, DOE's challenge will be to understand clearly what the commercial market demands. In-Q-Tel benefits greatly from a very close relationship with our primary customers, the CIA and the broader Intelligence Community. For DOE to succeed, they will, in my view, need to find means to accurately gauge future demands as well as opportunities in the commercial energy markets. It is also worth noting that the demands and opportunities in the energy market are influenced significantly by policy and regulation in the field. As with many markets, the regulatory environment may discourage, or conversely, encourage, venture investment in the energy market.

In-Q-Tel has always positioned itself carefully with respect to its operations as a government-funded venture capital firm in a civilian market. In-Q-Tel's position has been that the government should not be competing with private money—but rather, the government should be using a small amount of government funds to take advantage of the genius of the VC system—in a careful and thoughtful way—to benefit unique government needs and thereby the whole nation. If DOE intends to use the In-Q-Tel model to develop technology for the commercial market only, not the government market, I believe some modification of In-Q-Tel's model will be necessary to adapt it to DOE's purposes.

Questions submitted by Representative Bart Gordon

Q1. What do you consider to be the most pressing challenge we face in energy? Will the cumulative efforts of our current federal civilian, university and industrial R&D infrastructure give us a solution to that challenge?

A1. There are clearly energy challenges facing our country and our economy including decreasing reliance on foreign sources, increasing efficiency in energy use, and broadening our set of resource options. My testimony to the Committee addressed a means by which the intelligence community accesses the innovations generated by our country's civilian, university and industrial R&D infrastructure in order to address some of the hardest challenges the Intelligence Community faces. In-Q-Tel does not so much invent new innovations as accelerate the rate at which the intelligence community can benefit from existing innovations, and find new ways to use technology to solve problems.

The current federal civilian, university, and industrial R&D infrastructure has obviously helped American ingenuity become the envy of the world. In-Q-Tel has assembled an agile team of technology and business experts who comb through that infrastructure to identify and strengthen technology solutions that can address capability needs of the Intelligence Community.

In-Q-Tel has a broad and robust outreach policy aimed at tapping all sources of technology. In addition to soliciting business plans via its web site *www.In-Q-Tel.org*, In-Q-Tel actively scouts for technologies and investment opportunities by capitalizing on its technology network that includes other venture investors, univer-

sity faculty and technology commercialization offices, national and corporate laboratory researchers and their licensing offices, and program managers at government funding agencies.

In-Q-Tel has engaged with nearly 90 commercial companies, most of which were previously unknown to the government, and 11 universities and research labs, which In-Q-Tel identified through its commercial and academic outreach programs. In-Q-Tel has received and reviewed over 5,500 business plans, and we have also cultivated a network of more than 200 venture capital firms and 100 labs and research organizations, further broadening Intelligence Community access to innovative technologies.

Once having identified promising technological solutions, In-Q-Tel uses the strength of the marketplace to deliver those capabilities to the intelligence community. For every dollar of investment In-Q-Tel makes, we leverage an average of $8 of private investment in bringing technologies to the market. In our six-year history we have delivered significant mission impact to the CIA and the broader Intelligence Community, resulting in the application of more than 120 technology solutions and leveraging more than one billion dollars in private sector funding to support R&D that matches government needs.

This outreach—and the corollary of strengthened connectivity between the many different aspects of our national research, development, testing, evaluation, marketing, and deployment efforts—has helped In-Q-Tel address many of the most pressing challenges faced by the intelligence community. A similar approach directed at energy challenges may be valuable as part of an overall integrated strategy to address these challenges.

Q2. If you were the Director of ARPA–E what three potentially transformational technologies would you be likely to pursue?

A2. In-Q-Tel does not purport to have the deep technical experience in energy that the director of ARPA–E will have. In-Q-Tel does have experience making bets on technology, however. In-Q-Tel has embraced a portfolio strategy for delivering value to the intelligence community. Because our government partners have critical technology needs, when we do early stage investing, we frequently invest in multiple component technologies that together provide a viable solution.

One of the strengths of the venture investing model is that In-Q-Tel's own technology, market, and business assessments are validated by the diligence conducted by its co-investors. Over the six years that In-Q-Tel has been in operation, In-Q-Tel has developed a reputation for conducting among the most rigorous technical due diligence in the investment community, and In-Q-Tel has found that other investors rely on In-Q-Tel's assessment of the soundness of technologies it examines.

In the context of your question, if ARPA–E adopted elements of In-Q-Tel's venture investing model, the selection of research and development projects to be undertaken by any additional Department of Energy effort could be guided and informed by realistic insight into potential market adoption and use.

Q3. To your knowledge, is the current organizational structure of the Department of Energy and its various programs conducive to generating truly transformational energy technologies? Where is it lacking?

A3. I will defer to others for the evaluation of the Department of Energy's structure.

Q4. Do you believe that a DARPA-like program for energy can attract industrial interest sufficient to bring about real change in the energy technology sector? What are the barriers for industrial participation?

A4. Assuming a healthy supply of new technologies being created as a result of basic research funding, as I noted in my written testimony, the barriers to attracting sufficient private sector resources to bear on bringing new technologies to the market can all be distilled down to one factor: money in the marketplace. Companies will only take on the task of productizing a new technology if there is a high probability that they will make money selling the product. That statement is true regardless of whether the customer for the product is the Government or the wider commercial market.

So while In-Q-Tel's venture capital model is not a substitute for fundamental research funding, we have provided significant added value to the Intelligence Community by leveraging government and private sector investments in research. In fact, the majority of the companies in which In-Q-Tel has invested have their roots in fundamental research conducted at universities and laboratories supported by NSF, DOE, ONR, and DARPA. Moreover, before the products are delivered back to the Government, other private investment capital in addition to In-Q-Tel's has been

invested in the companies, leveraging additional private sector resources to deliver a better product to government.

As an investor, In-Q-Tel can influence the product development roadmap to ensure that the commercial products will indeed meet the Intelligence Community's needs while adding value for the commercial customers as well. Among the advantages of commercial technology are lower initial and long-term costs, easier integration, longer technology lifetime, faster development, better user interfaces, incremental upgrades, and next-generation improvements, all developed by leveraging success in the commercial marketplace. Our success stems from linking commercial viability and technical excellence with our government partners' needs.

Q5. To the extent that you are familiar with the energy research conducted in the Department of Defense, do you see potential linkages between any current research activities at DARPA and the research that would be conducted through ARPA–E?

A5. Speaking from the perspective of an independent but government-funded innovation accelerator that is somewhat agnostic as to the source of innovations we bring to bear on Intelligence Community problems, I can best respond regarding linkages between potential approaches instead of specific research initiatives.

As the Committee has noted, some have suggested that an ARPA–E should be designed to foster directed basic research, and other proponents suggest its role should be to get products into the marketplace. In-Q-Tel was founded to address a specific and unique challenge that is somewhat related: namely, how to provide the U.S. Intelligence Community with access to the technology innovations being brought to the commercial market by small, start-up companies, or other sources of innovation such as national labs and universities, who may not target the Government for sales. Like any other venture investor, In-Q-Tel "cherry picks" technologies with high potential for commercial success. Because In-Q-Tel is a strategic investor for the Intelligence Community, In-Q-Tel selects from the entire range of commercially viable technologies those that have relevance to Intelligence Community mission. Moreover, our portfolio approach to investment leads us to invest in multiple technologies, from varied sources, that when linked together may form an end-to-end solution to a problem that no single technology or source would address as effectively. Indeed, because In-Q-Tel is not the source of the technologies themselves, we evaluate multiple technologies from multiple sources objectively. As an investor, of course, we look for winners from across stovepipes and sometimes create winners by linking technologies from difference sources.

On the development timeline from incipient idea to fully productized, off-the-shelf commodity, In-Q-Tel typically engages sometime after the demonstration of a working prototype. That is, In-Q-Tel does not typically invest in early research the way that DARPA or other government funding agencies do, but rather, takes the output of early research and supports its development into technology products and sustainable commercial outlets from which to buy those products. In some cases, In-Q-Tel provides very directed "gap funding" to assist in bridging the so-called "valley of death" between the basic research funding and the point at which the technology opportunity is sufficiently mature as to readily attract institutional investors or, in the case, of DARPA, be ready for delivery under a DOD procurement or acquisition program. As a separate, commercially informed entity that can tap on all sources for technology solutions, In-Q-Tel has shown value for the Intelligence Community. Elements of In-Q-Tel's operations may contribute to solving energy challenges in a similar way.

Questions submitted by Representative Eddie Bernice Johnson

Q1. How do you feel about Mr. Gordon's legislation, H.R. 4435, establishing an ARPA–E?

A1. I will defer to others for the evaluation of proposed legislation.

Q2. What is your opinion about how an ARPA–E would be organized? Would the director report to the head of DOE's Office of Science or directly to the Secretary of Energy?

A2. I will defer to others for the evaluation of proposed Dept. of Energy structures.