THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY (ARPA–E): ASSESSING THE AGENCY'S PROGRESS AND PROMISE IN TRANSFORMING THE U.S. ENERGY INNOVATION SYSTEM

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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SECOND SESSION

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January 20, 2010

THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY (ARPA–E): ASSESSING THE AGENCY'S PROGRESS AND PROMISE IN TRANSFORMING THE U.S. ENERGY INNOVATION SYSTEM

WEDNESDAY, JANUARY 27, 2010

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

The Committee met, pursuant to call, at 10:04 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

BART GORDON, TENNESSEE
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Committee on Science and Technology

Hearing on

The Advanced Research Projects Agency – Energy (ARPA-E): Assessing the Agency's Progress and Promise in Transforming the U.S. Energy Innovation System

Wednesday, January 27, 2010
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witness List

Dr. Arun Majumdar
Director
Advanced Research Projects Agency – Energy (ARPA-E)

Dr. Chuck Vest
President
National Academy of Engineering

Dr. Anthony Atti
President and CEO
Phononic Devices, Inc.

Mr. John Denniston
Partner
Kleiner, Perkins Caufield & Byers

Dr. John Pierce
Vice President
Dupont Applied Sciences - Biotechnology

HEARING CHARTER

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

The Advanced Research Projects Agency–Energy (ARPA–E): Assessing the Agency's Progress and Promise in Transforming the U.S. Energy Innovation System

WEDNESDAY, JANUARY 27, 2010
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

The purpose of this hearing is to review progress made on establishing ARPA–E and discuss what differentiates ARPA–E from other DOE programs, hear accounts of experiences with the agency's first funding opportunities, examine the agency's plans and goals for the coming year, and discuss ways in which ARPA–E may be improved through reauthorization of the *America COMPETES Act*, as appropriate.

Witnesses

- **Dr. Arun Majumdar** is the Director of the Advanced Research Projects Agency–Energy (ARPA–E) at the U.S. Department of Energy. He was nominated by President Obama in September 2009 and confirmed by the Senate in October. Dr. Majumdar was formerly Associate Laboratory Director for Energy and Environment at Lawrence Berkeley National Laboratory and a Professor of Mechanical Engineering and Materials Science and Engineering at the University of California at Berkeley.
- **Dr. Charles Vest** is the President of the National Academy of Engineering and former President of the Massachusetts Institute of Technology (MIT). Dr. Vest served on the National Academies "Rising Above the Gathering Storm" panel, which proposed the creation of ARPA–E.
- **Mr. John Denniston** is a Partner at the venture capital firm Kleiner, Perkins, Caufield and Byers (KPCB). He is a leading expert on clean energy technology investment.
- **Dr. Anthony Atti** is the President and CEO of Phononic Devices, Inc, a small firm that originated at the University of Oklahoma. Phononic Devices received funding for development of thermoelectric energy conversion devices.
- **Dr. John Pierce** is the Vice President of Technology at DuPont Applied BioSciences. DuPont, a Fortune 100 company, was chosen to receive funding for development of processes to produce biobutanol from macroalgae.

Background

The Advanced Research Projects Agency–Energy (ARPA–E) was originally authorized in the *America COMPETES Act of 2007* [P.L. 110–69]. That Act followed on the direct recommendations of the widely-acknowledged 2005 National Academies report, "Rising Above the Gathering Storm." The "Gathering Storm" panel was chaired by retired Lockheed Martin Chairman and CEO Norman Augustine, and included, among a number of experts on innovation, the current President of the National Academy of Engineering, Dr. Charles Vest, the current Secretary of Defense, Dr. Robert Gates, and the current Secretary of Energy, Dr. Steven Chu. The panel made a series of recommendations to enhance the nation's technological competitiveness, including a recommendation calling on the Federal Government to create a new energy research agency (ARPA–E) within Department of Energy patterned after the successful Defense Advanced Research Projects Agency (DARPA) within the Department of Defense.

According to the Gathering Storm report, ARPA–E should be structured to "sponsor creative, out-of-the-box, transformational, generic energy research in those areas

where industry itself cannot or will not undertake such sponsorships, where risks and potential payoffs are high, and where success could provide dramatic benefits for the Nation . . . . 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."

Several other components of the panel's recommendations were included in the COMPETES Act, including extending special personnel and contracting authorities, hiring of staff for limited terms of approximately three years, and authorizing $300 million in initial year funding. COMPETES differs from the "Gathering Storm" recommendations primarily by having the Director of ARPA–E report directly to the Secretary of Energy, further reducing bureaucratic inefficiencies and enhancing decisionmaking powers of the Director. The *America COMPETES Act* was signed into law in August 2007.

Despite being authorized in 2007 it was not until 2009 that ARPA–E received funding. The *American Recovery and Reinvestment Act of 2009* [P.L. 111–5] included allocations of $400 million for ARPA–E to become fully operational. At the same time, *Fiscal Year 2009 Omnibus Appropriations Act* appropriated $15 million for the start-up of ARPA–E.

Passage of the Recovery Act served as the launch point for ARPA–E. However, the stipulations for funding under the Recovery Act provided a unique and challenging situation for the Department in standing up ARPA–E by requiring that agencies obligate all funds by the end of fiscal year 2010. Therefore, within this timeframe of less than two years, the Department would have to establish ARPA–E, overcome logistical challenges such as acquiring office space and hiring core staff and contractors, announce opportunities for project funding, conduct intensive project selection processes, make a large number of awards and complete the contracting process with award recipients, oversee the execution of these projects with high degree of interaction with performers, and terminate funding for projects that did not appear promising. Furthermore, the Director of ARPA–E required Presidential nomination and Senate confirmation. To date, despite very limited staffing and an unexpectedly high number of applications, ARPA–E has met all specified deadlines and obligations.

Shortly after receiving Recovery Act funding, ARPA–E released its first Funding Opportunity Announcement (FOA) in April 2009, and it received an unprecedented response. The scope of the announcement was broad, limiting applications simply to "transformational" technologies. Furthermore, to reduce the administrative burden on both ARPA–E staff and applicants and to mitigate costs associated with a full application, the FOA called for submission of concept papers of only eight pages or less. Consequently, ARPA–E received almost 3,700 concept papers. After an intensive selection process utilizing expert volunteers from industry and academia, 334 of those were chosen to submit full applications. Ultimately, 37 projects were chosen to participate, totaling over $150 million in awards to a diverse range of technologies and performers. A detailed list of awards can be found here: *http://www.energy.gov/news2009/documents2009/ARPA–E_Project_Selections.pdf*

ARPA–E also follows an aggressive schedule for negotiating and signing contracts with performers. For the first round of funding, ARPA–E completed all of the award contracts within three months after the award announcement, and most within two months. By all accounts this is a rapid pace for Federal contracting and represents a 60% reduction over the average Department of Energy procurement cycle time.

A second round of solicitations totaling $100 million was announced in early December. Informed by a series of open workshops the second round focuses on three distinct areas: innovative materials and process for carbon capture, transportation batteries, and liquid fuels from carbon dioxide. The deadline for submission was January 15, 2010. Despite the comparatively narrow scope of this solicitation, ARPA–E received over 600 concept papers. It is expected that awards will be announced in the spring of 2010, totaling 30–40 projects, and a third round of solicitations will be announced in a similar timeframe.

Given the high demand for both the first and second rounds of funding, it became clear that ARPA–E had the financial and human capacity to accommodate only a small percentage of applications. Assuming that many more projects were worthy of funding, and that those that did receive ARPA–E awards would ultimately have to secure private sector funding, the Department announced that it would work with outside organizations to hold an ARPA–E Energy Innovation Summit on March 1–3rd. The summit is expected to highlight projects that both received awards and those that did not receive awards but might be of interest to the investor community. Securing private sector funding for projects, either as cost-share on projects or follow-on investment after project completion, is critical to commercializing success-

ful innovations from ARPA–E. Detailed information on the ARPA–E Energy Innovation Summit can be found here: *http://www.ct-si.org/events/EnergyInnovation/*.

For more information on the hearing please contact Chris King at 225–8844 or *Christopher.king@mail.house.gov*

Chairman GORDON. Good morning. I want to welcome everyone to the hearing on the Advanced Research Projects Agency for Energy, or ARPA–E. It was almost a year ago that ARPA–E received startup funding. We can consider this hearing their first annual check-up.

Today we will discuss the rather brief but dynamic history of ARPA–E, including some of the early achievements and future plans for the Agency. We will also hear from witnesses on the role of ARPA–E in the larger energy technology landscape and how it can best be positioned to serve as a driver of job creation and technological competitiveness in the United States.

This Committee has a lot invested in ARPA–E. Though the *America COMPETES Act* was a product of bipartisan negotiation between the House and Senate, it is really this Committee that has led the charge in ensuring that ARPA–E became a reality.

In 1958 DARPA [Defense Advanced Research Projects Agency] was created in response to Sputnik, and today we must respond to the serious threat of China and others that see leadership in clean energy technology development as key to their economic growth.

Just as the originators of DARPA can look back on its successes, the internet, stealth technology, and GPS among many others, I firmly believe that in the not-so-distant future, Members of this Committee will look back on our role in the formation of ARPA–E and take great pride in the technological breakthroughs and new industries that will inevitably result from its work. ARPA–E will in turn serve as a model for innovation in other programs within the Department of Energy and other Federal agencies.

We were very fortunate that the President chose Dr. Steven Chu to lead the Department. Along with Dr. Vest, who is with us today, Secretary Chu was instrumental in seeing that the National Academy of Sciences' *Rising Above the Gathering Storm* report included a recommendation to establish ARPA–E. They clearly understood the threats to competitiveness and the call for new models of research and development.

As Tom Donohue, the CEO of the U.S. Chamber of Commerce, said in a hearing last week, "The creation of ARPA–E represents a bold step towards bypassing some of the traditional stove-piping that frequently hinders the efficiency and expediency of research and development at DOE and its National Laboratories."

Over the last four years I have become a believer that the DARPA model will work for energy, and that it was just what the Department needed to overcome long-standing institutional barriers to innovation.

I think we can all appreciate a small, non-bureaucratic group of very talented individuals armed with the resources to quickly respond to high-risk technological challenges and, just as quickly, to terminate unsuccessful projects. This team has the singular mission to do whatever it takes to develop the most cutting-edge, clean energy technologies and get them into the marketplace as quickly as possible.

Dr. Arun Majumdar and his team understand their mission better than anyone. They understand that their challenge is to be innovative not only in the projects they undertake, but also in how they undertake them. They appear unafraid, confronting the tradi-

tional bureaucratic hurdles and trying new models to spur innovation. And let me give you one quick example of that. On two different occasions, Dr. Majumdar and Dr. Chu came to see me, and on each occasion I said that there are more good ideas for energy innovation than there are dollars, public dollars, available. And we need to have some type or find some way to put those private dollars with the good ideas.

I also told each of them that when they go back to the office, their lawyers are going to give them 100 reasons why they can't do this, and they just need to say "I want one reason why I can." Miraculously, I guess because they haven't been in town very long, they came up with that one reason, and now next month there is going to be a seminar affair to help them develop that community within ARPA–E as well as hopefully to bring more public-sector dollars to the table. And as I have been around them, I can tell you firsthand, this really is a band of brothers and sisters that have come together with a singular bond, and that is to really help this country, both in terms of energy independence and job creation with new industries.

Many of them, well, I won't say many of them, I think all of them left jobs and took pay cuts to come to Washington. They virtually all had to interrupt a successful career, and because you are only going to be here for two or three years, many of them left their families at home so the kids could stay in school. So they are here on a mission, and even though you can tell I am very supportive of that mission, this Committee still has a job of oversight. And so we need to make sure that they take this good idea and maximize it to its fullest extent.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

Good morning. I want to welcome everyone to this hearing on the Advanced Research Projects Agency–Energy, or ARPA–E. It was almost a year ago that ARPA–E received startup funding from the Recovery Act. We can consider this hearing their first annual check-up.

Today we will discuss the rather brief but dynamic history of ARPA–E, including some of the early achievements and future plans for the agency. We will also hear from witnesses on the role of ARPA–E in the larger energy technology landscape, and how it can best be positioned to serve as a driver of job creation and technological competitiveness in the U.S.

This Committee has a lot invested in ARPA–E. Though the *America COMPETES Act* was very much a product of bipartisan negotiations between the House and Senate, it is really this Committee that has led the charge in ensuring that ARPA–E became a reality.

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of the traditional 'stove piping' that frequently hinders the efficiency and expediency of research and development at DOE and its National Laboratories."

Over the last four years I have become a believer that the DARPA model will work for energy, and that it was just what the Department needed to overcome long-standing institutional barriers to innovation.

I think we can all appreciate a small, non-bureaucratic group of very talented individuals armed with the resources to quickly respond to high-risk technical challenges and, just as quickly, terminate unneeded projects. This team has the singular mission to do whatever it takes to develop the most cutting edge clean energy technologies and get them into the marketplace as quickly as possible.

I have followed very closely the progress of ARPA–E, and I can safely say that I am very encouraged by what I have seen. Dr. Majumdar and his team understand their mission better than anyone. They understand that their charge is to be innovative not only in the projects they undertake, but also in how they undertake them. They appear unafraid of confronting the traditional bureaucratic hurdles and trying new models for spurring innovation.

Chairman GORDON. And so with that, I now recognize our Ranking Member, my good friend and distinguished member from Texas, Ralph Hall.

Mr. HALL. Mr. Chairman, thank you for your usual good opening statement. I think I just ought to start with there is little if any disagreement on this Committee on the importance of fundamental advances in energy technologies to America's future economic national security. It is a priority that all of us and all of our members share and a principle for which we are able to work together and have worked together.

The challenge lies in how best to structure the Federal Government's involvement in energy R&D to maximize the use of all the resources. For a number of reasons, I don't know how many, I opposed the creation of ARPA–E in 2007. I was concerned that the DARPA model could not be applied successfully to the energy sector. I was concerned about the lack of clarity and the mission and scope of ARPA–E and whether it could result in government interference in private markets. I was also concerned that the creation of a new agency would compete with and reduce funding for DOE's Office of Science which was a top priority of The Gathering Storm report as well as our America COMPETES legislation.

Now, over two years since the legislation that established ARPA–E was signed into law, my original concerns largely remain. This is primarily because the agency's operations are still in the formative stages with the first round of grants being announced just last fall. The absence of a record upon which to make and form judgments regarding ARPA–E may be the most difficult aspect of this reauthorization. Without such a record, I am afraid we are left in a mostly conceptual debate similar to the one we had in 2007. Accordingly, I expect that we will ask many of the same questions, but this time maybe the answers will be different or at least more meaningful, since we have the benefit of a new ARPA–E director to provide responses and help us understand his vision for the agency.

I thank Chairman Gordon for working closely with me and with us on these issues and for assembling this distinguished panel of experts today. In as much as ARPA–E is now the law, which we supported as part of the *America COMPETES Act*, I want to work with this good Chairman as the program gets off its feet to make sure that it is the success that he believes and he is entitled to see.

And I yield back my time.

[The statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you, Mr. Chairman, for calling this hearing today on the Department of Energy's Advanced Research Projects Agency, or ARPA–E.

There is little if any disagreement in this Committee on the importance of fundamental advances in energy technologies to America's future economic and national security. It is a priority that all of our Members share, and a principle from which we are able to work together.

The challenge lies in how best to structure the Federal Government's involvement in energy R&D to maximize use of limited resources.

For a number of reasons, I opposed the creation of ARPA–E in 2007. I was concerned that the DARPA model could not be applied successfully to the energy sector. I was concerned about the lack of clarity in the mission and scope of ARPA–E, and whether it could result in government interference in private markets.

And I was concerned that creation of a new agency would compete with and reduce funding for DOE's Office of Science, which was a top priority of the "Gathering Storm" report as well as our America COMPETES legislation. Now, over two years since the legislation establishing ARPA–E was signed into law, my original concerns largely remain. This is primarily because the agency's operations are still in the formative stages, with the first round of grants being announced just last Fall.

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I thank Chairman Gordon for working closely with me on these issues and for assembling this distinguished panel of experts today. Inasmuch that ARPA–E is now law—which we supported as part of the *America COMPETES Act*—I want to work with the Chairman as the program gets off its feet to make sure it is the success that he believes it can be.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good Morning. Thank you, Mr. Chairman, for holding today's hearing to review the progress made on establishing the Advanced Research Projects Agency–Energy (ARPA–E) in the Department of Energy (DOE) and to discuss opportunities to improve the agency as we reauthorize the *America COMPETES Act*.

I was pleased to support the *America COMPETES Act* when it passed Congress with bipartisan support in 2007 and was signed into law by President Bush. Based on the recommendations of the 2005 report, *Rising Above the Gathering Storm*, the *America COMPETES Act* created ARPA–E, a government agency designed to invest in high-risk, high-reward energy research. In 2009 ARPA–E received $400 million in funding through the *American Recovery and Reinvestment Act*, and the *Fiscal Year 2009 Omnibus Appropriations Act* provided $15 million. I commend DOE, Dr. Majumdar, and the staff of ARPA–E for their hard work and efficiency in establishing the agency and awarding $150 million in less than one year to 37 award recipients.

While ARPA–E is instrumental in providing the initial investment in these research projects, additional funding will be necessary to move these innovative projects towards development, demonstration, and commercialization. I am interested to hear from our witnesses what programs, if any, are in place to assist the continued development of these projects.

Finally, as a supporter of clean coal technology, I was pleased ARPA–E provided funds to five carbon capture and storage (CCS) projects in its first round and will focus their next round of awards on investing in CCS. This next phase will have an immediate impact on our energy independence by enabling our coal plants to demonstrate that coal be used to cleanly and efficiently reduce our dependence on foreign oil.

I welcome our panel of witnesses, and I look forward to their testimony. Thank you again, Mr. Chairman.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

It is clear the Advanced Research Projects Agency–Energy (ARPA–E) is taking our Country a step in the right direction. ARPA–E, modeled after the highly successful Defense Advanced Research Agency (DARPA) within the Department of Defense provides funding for projects that have the potential to revolutionize American society. I am proud to have been a co-sponsor of the legislation that created this program and I strongly support its continuation.

It is vital for our Country to move forward by funding research that creates alternative forms of energy and technology that will lead us to a more prosperous future both environmentally and economically. If we continue to invest heavily in finite resources there is nothing to prevent those costs from skyrocketing when the supply runs low. The national security implications of the rapid escalation of energy costs must not be ignored. The time is now to invest in renewable energy. The time is now for ARPA–E.

Despite being funded for just one year, ARPA–E has shown its promise. Investing in projects that may one day revolutionize battery technology, motors, electronic and vehicle technologies may one day spur the renewable energy revolution.

I am disappointed that not one project from the state of Texas was selected in the first round of ARPA–E awards. Texas is home to many of the nation's leading businesses and research institutions dedicated towards funding renewable energy research. Out of all states, Texas ranks second in the Nation for its total number of alternative fuel vehicles; fifth for wind energy production; and eighth in total renewable energy R&D expenditures. The state of Texas has been a leader in alternative energy projects and research.

I would like to thank our witnesses for their time, insight and evaluation of this vital program. 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.

Chairman GORDON. Thank you, Mr. Hall. And panel, you can see your charge today is to make this bright, able person better understand what we see in ARPA–E. And it is my pleasure to introduce a very distinguished panel following upon an excellent panel last week.

First we have Dr. Arun Majumdar, who is the Director of ARPA–E and formerly the Associate Laboratory Director for Energy and Environment at the Lawrence Berkeley National Laboratory. Dr. Chuck Vest is the President of the National Academy of Engineering and a valued member of the *Rising Above the Gathering Storm* panel. Dr. Tony Atti is the President and CEO of Phononic Devices, and Mr. John Denniston is a partner in the firm of Kleiner Perkins Caufield & Byers, and finally Dr. John Pierce is the Vice President of DuPont Applied Sciences in Biotechnology. And I also would like to recognize John Gage who is here observing, who is a longtime technology leader in Silicon Valley, and I am sure that John Denniston will call upon you if he gets stuck to answer any kind of questions.

So Dr. Majumdar, you are recognized for five minutes.

STATEMENTS OF DR. ARUN MAJUMDAR, DIRECTOR, ADVANCED RESEARCH PROJECTS AGENCY–ENERGY (ARPA–E)

Dr. MAJUMDAR. Thank you very much. Chairman Gordon, Ranking Member Hall, and distinguished Members of this Committee, I am delighted to appear before you today and testify as the first Director of the Advanced Research Projects Agency for Energy, or ARPA–E. I am grateful for the trust that President Obama and Secretary Chu have placed in me. I also want to thank Congress

for authorizing ARPA–E in the *America COMPETES Act* and for appropriating $400 million in the *American Recovery and Reinvestment Act of 2009*. I am very excited about this opportunity to identify and invest in high-risk, high-payoff research and development that can transform our domestic and global energy landscape.

As you know, ARPA–E was modeled after DARPA, which was created in 1958 in response to the launch of Sputnik when it was felt that the United States had lost its technological lead. The United States now faces three Sputnik-like challenges: energy security, U.S. technological lead, and greenhouse gas emissions and climate change. In many cases, we as a Nation are lagging behind, and we need to change course with fierce urgency. ARPA–E's goal is to help catalyze this change.

Let me give you a quick report of where we are now and some thoughts on how to move forward.

The first funding opportunity announcement received an overwhelming response from the technical community: 3,700 concept papers, 340 full proposals, and, after a thorough review process, 37 proposals selected for award at an average of $4 million each. These projects were selected based on the impact on our mission, innovative technical approaches, superb teams, opportunities for the United States to gain leadership and to pursue technologies that are underserved by other parts of DOE and the private sector. If successful, these technologies could be game-changing and launch new opportunities for American businesses and jobs.

The $150 million of ARPA–E investment in this round catalyzed an additional $33 million in investment in two months, mostly from the private sector. Equally important, today ARPA–E has already negotiated 36 out of the 37 awards in less than three months.

While the first round was a clear success, the large oversubscription meant that there were many innovative ideas that we could not support with funding. We are bringing many of those teams back to ARPA–E through workshops and new programs. The ARPA–E Energy and Innovation Summit which will be held in Washington, D.C. on March 2 and 3 will not only showcase ARPA–E technologies, but will also introduce teams that we could not fund to other funding sources. I invite you and your staff to attend this event.

The second round funding opportunity announcement drew on the lessons from these workshops and will focus on advanced batteries for transportation, new materials and processes for carbon capture, and new ways of generating transportation fuel from hydrogen, carbon dioxide and electricity. The third round will be announced in early March. The goal of these rounds is to either identify technologies that will leapfrog over today's approaches or to create technologies where none currently exist.

If I have any concern for the future, it is the following: While ARPA–E's focus is to invest upstream in the energy innovation pipeline, we must keep the scaling of these innovations within the United States and thereby create new jobs in the energy sector. The purpose of the ARPA–E and the Innovation Summit is to explore how to achieve this. In this regard, I may note that the government is the Nation's largest energy consumer. I urge Congress

to consider using the government's purchasing power to create a demand pull for American innovations so that our businesses can get a foothold once they meet or exceed market-based performance and cost metrics. This will be critical in scaling up innovations and creating new jobs within the United States, especially in manufacturing, and it will enable American taxpayers to reap the benefits of their upstream investments through ARPA–E.

I recognize that these early days are a very critical period for ARPA–E. We are putting together our DNA, and we must get this right by innovating in our internal processes. We have a new organizational structure that is not only nimble and agile but one that breaks down potential silos between various disciplines and encourages internal debate and discussion, as well as coordination with the rest of DOE. I am delighted to report that we have been able to recruit some of the best and brightest from the technical community as program directors to serve in ARPA–E for a limited time. These are a rare breed of people who are some of the most active scientists and engineers with one foot in science and technology development and the other in business. We have also created an ARPA–E fellows program to recruit some of the best young minds to join ARPA–E for a maximum of two years and help us craft new programs by identifying technological opportunities in the global energy landscape.

From my past experience in the R&D community and through what I have now seen through ARPA–E, I can assure you that the innovation process in the United States is in full swing. Energy is now receiving the attention of the best minds in our country and is attracting new talent. I am confident in saying that we are not limited by lack of good ideas. We still have the best R&D infrastructure in the world and a thriving innovation ecosystem in business and entrepreneurship. I am very optimistic about our Nation's future.

I pledge to use all my knowledge, expertise and experience to continue growing ARPA–E into a robust engine for American innovation and energy environment. I once again thank you for your support.

[The prepared statement of Dr. Majumdar follows:]

PREPARED STATEMENT OF ARUN MAJUMDAR

Chairman Gordon, Ranking Member Hall, and Members of this Committee, thank you for the opportunity to testify today on the Advanced Research Projects Agency–Energy (ARPA–E).

As the first Director of ARPA–E, I am also grateful for the opportunity to create an organization within the DOE with a mandate to identify and support the innovative and pioneering ideas and people that will be game-changing for our domestic and global energy landscape. It has been incredibly exciting for me and my team. Prior to my current job, I was a Professor of Mechanical Engineering and Materials Science and Engineering for 13 years at the University of California, Berkeley, as well as a scientist and the Associate Laboratory Director for Energy and Environment at the Lawrence Berkeley National Laboratory. I have been involved in R&D for the last 25 years and am an elected member of the National Academy of Engineering.

I want to thank President Obama and Secretary Chu for their trust in me to serve as the first Director of ARPA–E, the Senate for confirming me in this position, and to Congress for authorizing and appropriating ARPA–E. I especially want to recognize Chairman Gordon and the Members of this Committee for all of their hard work in authorizing ARPA–E in the *America COMPETES Act*.

Many people within the DOE have my deepest gratitude for their work to help launch ARPA–E before I joined as its Director on October 26, 2009. These include Secretary Chu himself, Undersecretaries Kristina Johnson and Steve Koonin, CFO Steve Isakowitz, DOE's *American Recovery and Reinvestment Act* Recovery Act Implementation team led by Matt Rogers, Shane Kosinski, as well as many staff members from the Offices of the General Counsel, and Procurement, along with the technical staff from the Office of Science and the Applied Energy Offices. I was very blessed to have their support before I joined, and I continue to rely on their expertise and effort.

1. Introduction

As this committee well knows, our dependence on fossil fuels threatens our energy and environmental security and creates significant challenges in addressing climate change. Business as usual is not a viable option. Conversely, taking swift action on energy is a tremendous economic opportunity to lead in what Secretary Chu has called another industrial revolution. The nation that successfully grows its economy with more efficient energy use, a clean domestic energy supply, and a smart energy infrastructure will lead the global economy of the 21st century. In many cases, we are lagging behind. We as a nation need to change course with fierce urgency.

ARPA–E was created to address this important issue, and it was created with DARPA as a model. It is important to understand the origins of DARPA, and also point out some of the key differences between the defense and energy sectors of our economy. DARPA, originally called ARPA, was created in 1958 in response to the launch of Sputnik by the Soviet Union. It was felt at the time that the U.S. had lost its technological lead, and that the Nation needed an organization that would invest in high-risk/high-payoff R&D and connect technological innovation to business, which would then support the defense infrastructure.

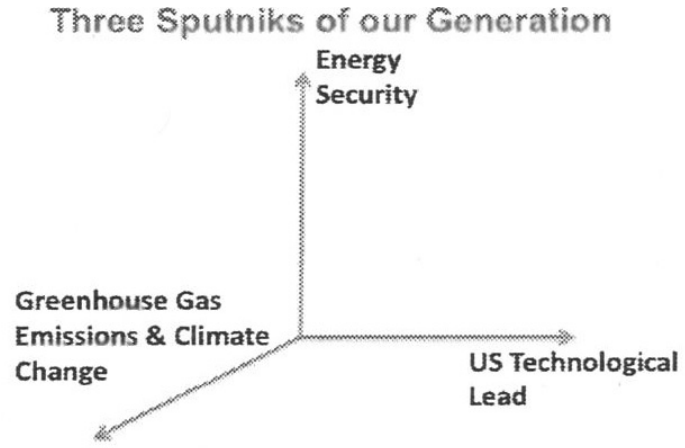


Fig. 1 The U.S. is now facing three "Sputniks" of our generation

The U.S. now faces three Sputnik-like challenges in the energy and climate area (see Figure 1): (a) energy security; (b) U.S. technological lead; and (c) greenhouse gas emissions and climate change. To illustrate where we are, I have included two snapshots of production key to future energy use. Figure 2 shows the trends in U.S. market share and shipments of photovoltaic solar cells—in a span of 15 years, the U.S. market share has decreased from 45 percent to less than 10 percent. Figure 3 shows the manufacturing volumes of Lithium-ion batteries in 2009. These batteries are being used in both mobile electronics (laptop computers, cell phones, etc.) as well as for plug-in hybrid and electric vehicles. It is noteworthy that the materials and chemistry that are used in these batteries were largely discovered here, yet the United States has about one percent of the global manufacturing volume.

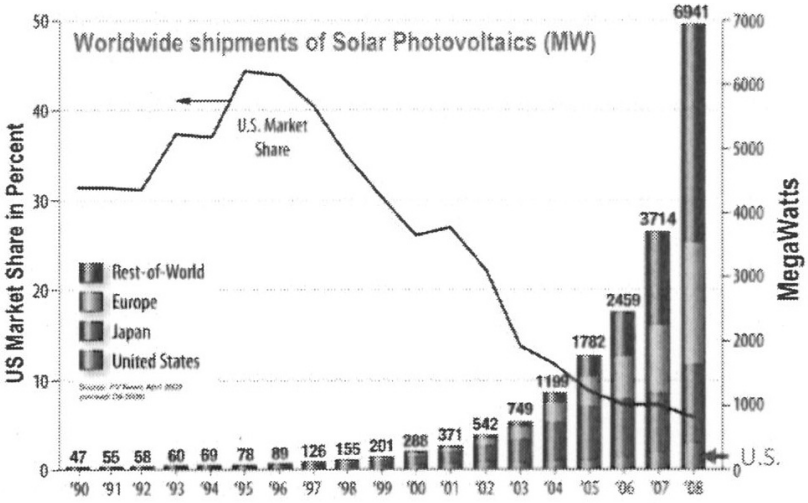


Fig. 2 Global comparison of solar cell shipments. Source: PV News, April 2009.

2. Scale and Pace of Innovation Needed in the Energy Sector

During the 20th century, certain key innovations changed the course of human history, including the Haber-Bosch process of creating artificial fertilizers by fixing atmospheric nitrogen to form ammonia. It touched humanity like none other because it led to massive increase in food production and an almost four-fold increase in global population in 100 years. Other game-changers included creating semi-dwarf, high-yield strains of wheat that introduced the green revolution; antibiotics; polio vaccination; the transistor and integrated circuits; electrification; the airplane; nuclear energy; optical and wireless communication; the internet; and more. Now imagine all of these innovations happening in a span of just 10–20 years: That is the scale and pace of game-changing innovations that we need to address the energy and climate change challenge we face. In short, the next 20 years need to be the most innovative period in our Nation's history.

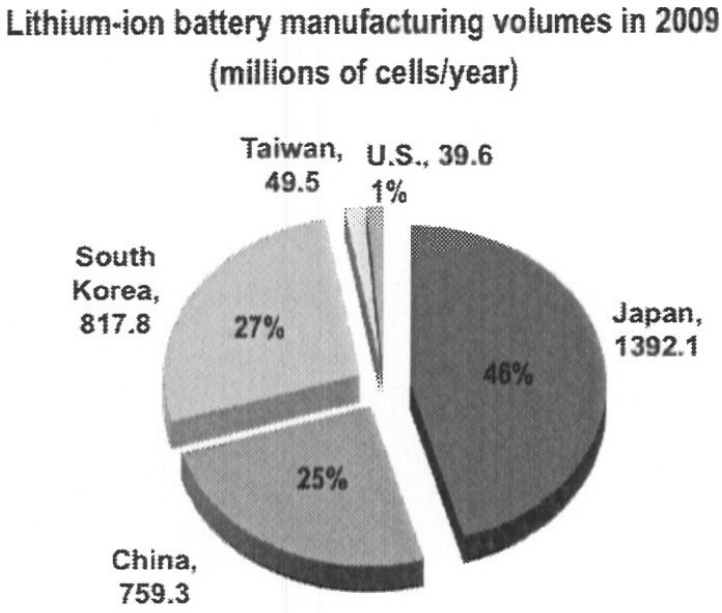


Fig. 3 Global distribution of manufacturing volume of Lithium-ion batteries in 2009.

Our history is replete with examples of pioneers and entrepreneurs who took risks. These innovators often failed initially, but quickly learned from those failures, competed against each other, and innovated in both technology and business to create the largest industrial base the world has ever seen.

ARPA–E's goal is to tap into this truly American ethos, and to identify and support the pioneers of the future. With the best R&D infrastructure in the world, a thriving innovation ecosystem in business and entrepreneurship, and a generation of bright young minds that is willing to engage with fearless intensity, we have all the ingredients necessary for future success. The goal of ARPA–E is to harness them to address our technological gaps and leapfrog over current approaches.

3. Creation of ARPA–E

Recognizing the need to reevaluate the way the United States spurs innovation, the National Academies released a 2005 report, "Rising Above the Gathering Storm", that included the recommendation to establish an Advanced Research Projects Agency–Energy (ARPA–E) within the Department of Energy (DOE). In August of 2007, Congress passed the *America COMPETES Act* which, among many of the recommendations in the National Academies report it codified, established ARPA–E with the following objectives:

1. To bring a freshness, excitement, and sense of mission to energy research that will attract the U.S.'s best and brightest minds—those of experienced scientists and engineers, and, especially, those of students and young researchers, including from the entrepreneurial world;
2. To focus on 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. To 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; and

4. To create a new tool to bridge the gap between basic energy research and development/industrial innovation.

President Barack Obama announced the launch of ARPA–E on April 27, 2009, as part of a sweeping announcement about Federal investment in research and development and science education. The *American Recovery and Reinvestment Act of 2009* provided $400 million in funding for ARPA–E.

With the first tranche of those funds having been awarded, I would like to provide a report on where we are now and our plans for the future.

4. First Funding Opportunity Announcement

4.1 Process: The first ARPA–E Funding Opportunity Announcement (FOA) was made in May 2009, and the FOA requested concept papers of transformational ideas spanning all aspects of energy science and technology. ARPA–E received approximately 3700 concept papers, significantly higher than expected. After these concept papers were reviewed, roughly 340 were invited to submit full proposals. These proposals were then reviewed by two sets of panels of external reviewers. Based on these reviews and a rigorous selection process, on October 26, 2009 the DOE selected awardees for $151 million of Recovery Act funds for 37 energy research projects under ARPA–E. The average funding level was $4M for a maximum of three years. The minimum and maximum funding levels were about $500K to $9M, respectively. Approximately 45% of the funding was received by small businesses, 35% by educational institutions, and the remaining 20% by large industry. National Laboratories team members participated in 19% of the funded projects.

Selections for ARPA–E's first FOA were announced Oct 26, 2009. By January 15, 2010, 35 out of 37 selections were awarded. This speed has now set records within the DOE, showing both the potential for ARPA–E to move quickly as consistent with its mission, and its ability to move Recovery dollars out the door in order to quickly create jobs.

4.2 Funded Projects: These 37 projects constituted the best ideas that, if successful, could be potential game-changers in the energy sector. These topics were chosen based on the following criteria:

- High impact on ARPA–E mission areas
- Innovative technical approaches
- Best-in-class people and teams
- Opportunities for U.S. to maintain/gain technology leadership
- "White Space" opportunities relative to existing DOE portfolio
- Topic areas underserved by private sector investment (e.g., both technical and market risk)
- Strong additionality/leveraged impact relative to private sector investment and other public funding programs

Let me provide a couple of examples from among the projects funded by the first FOA.

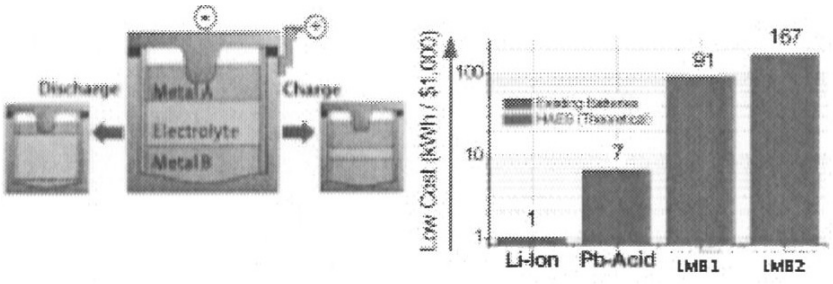


Fig. 4 Liquid metal battery could potentially be used for grid-level electrical energy storage (MW of power, MW-hr of energy) and at a cost of $50-100/kW-hr.

Figure 4 shows a large-scale liquid metal battery under development at the Massachusetts Institute of Technology. It is based on the innovative use of electroplating on two different metals from a mixture of two liquid metals. Based on low-cost, domestically available liquid metals, such a battery could lead to the mass adoption

of grid-scale electrical energy storage as part of the nation's energy grid. The estimated cost of such a battery would be roughly $50–100/kWhr, which would make it economical world wide. Grid-level electricity storage is one of the most challenging issues to make a "smart grid", and yet there are currently very few viable technologies that meet all the requirements for such an application.

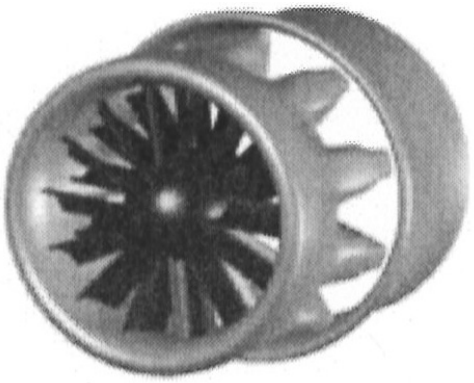


Fig. 5 New windmill design based on the engineering of jet engines

Figure 5 shows the design of a new wind turbine developed by FloDesign Corp, a startup company based in Massachusetts. Today's windmills look like propellers with large blades mounted on a rotating horizontal axle, and they have an inherent limit (the Betz limit), capturing a maximum of about 60% of the wind energy. Today's windmills operate at about 50–55% efficiency, which is seen as almost the practical efficiency limit. FloDesign has used concepts from jet engine fluid dynamics and innovated in windmill design, which has now been able to beat the Betz limit. This breakthrough enables FloDesign to reduce the cost and size of windmills by roughly 40% while maintaining the same power level. Furthermore, the major loads are no longer on the rotating shaft and bearing, but rather on the stationary envelop, which reduces reliability problems and increase lifetime.

4.3 Building a Constituency: The nature of projects selected in FOA–1 has energized and engaged the technical and investment community. In addition to unveiling a pent-up fountain of ideas as evidenced by the overwhelming response to the solicitation, private capital has begun to come off the sidelines, which was one of the main goals of the Recovery Act. After ARPA–E announced its selections, the teams collectively received about $30M of private investments in less than two months, suggesting that if ARPA–E can reduce the technology risk, the private sector is willing to adopt the technology and potentially scale it in the market.

In fact, one ARPA–E awardee went as far as to say, "*Winning the ARPA–E award served as the catalyst for an over-subscribed financing round and recruitment of business executives*."

4.4 Speed of Transactions: Selections for ARPA–E's first FOA were announced October 26, 2009. By January 15, 2010, 35 out of 37 selections were awarded. This speed has now set records within DOE, which is especially important considering that we are being funded through ARRA funds, all of which need to be obligated by September 30, 2010.

4.5 Supporting Projects Not Funded: One of my main goals in the near future is to nurture this interest in ARPA–E technologies. As noted above, of the 3,700 initial applications received, DOE only selected 37 for funding. Clearly, the first ARPA–E solicitation was oversubscribed and many excellent proposals could not be funded. We have encouraged and continue to encourage many of the teams who did not get funded to return to ARPA–E with their ideas for future workshops and to help us create new programs. We are also launching the ARPA–E Energy Innovation Summit March 1–3, 2009, in Washington, DC, where we not only want to highlight the technologies that we support, but also invite teams that did not get funded, so that we can connect them to other offices within DOE as well as other funding agencies and organizations. In short, I realize that we cannot financially support everyone,

but we also realize that we need to build a large community beyond ARPA–E for our nation to change course with fierce urgency.

5. Next Funding Opportunity Announcements

On the heels of the first funding opportunity's success, Secretary Chu announced on December 7, 2009 the availability of a second round of funding opportunities for transformational energy research projects through ARPA–E. Funding Opportunity Announcement 2 (FOA–2) will provide an additional $100 million in Recovery Act funding. In contrast to FOA–1, which was open to all topics related to energy, FOA–2 is focused on a set of three topics chosen from several workshops that ARPA–E hosted over a three-month period, where it received input from the technical community. Areas of focus included under FOA–2 are:

1. Electrofuels. ARPA–E seeks new ways to make liquid transportation fuels—without using petroleum or biomass—by using microorganisms to harness chemical or electrical energy to convert carbon dioxide into liquid fuels.
2. Innovative Materials & Processes for Advanced Carbon Capture Technologies (IMPACCT). To address the enormous challenge of reducing the cost of carbon capture, ARPA–E is looking for low-cost catalysts to enable systems with superior thermodynamics that are not currently practical due to slow kinetics, robust materials that resist degradation from caustic contaminants in flue gas, and advanced capture processes.
3. Batteries for Electrical Energy Storage in Transportation (BEEST). ARPA–E seeks to develop a new generation of ultra-high energy density, low-cost battery technologies for long electric range plug in hybrid electric vehicles and electric vehicles (EVs).

We are now in the process of organizing another set of workshops, the results of which we will use to plan the next set of FOAs (FOA–3) sometime in early Spring. FOA–3 will be the last funding under ARRA funds, and we will obligate these awards before September 2010.

6. The DNA of ARPA–E

I firmly believe that if we are to stimulate innovations in technology in the technobusiness community, ARPA–E itself must be innovative. My vision includes:

- *Organization*: Flat, nimble, agile, collaborative, internal debates and discussions;
- *Excellence in People & Ideas*: An all-star team at ARPA–E focusing on highly selective and potentially game-changing ideas;
- *Integrity*: New program creation and proposal review process;
- *Openness*: Open to best ideas regardless of origin, transparency, public understanding of value of technology for society, respond to community input;
- *Speed*: Streamline transactions and accelerate science to market;
- *Metrics of Success*: Quantitative value creation.

While we have adopted some best practices from DARPA based on statutory requirements as well as non-statutory ones, it is worth noting that the defense and energy sectors are by nature very different. The defense sector is almost a closed economy, and DARPA will always have a known customer, the DOD. On the other hand, the DOE budget is a fraction of whole energy sector, and ARPA–E is a fraction of that. Hence, ARPA–E needs to identify the customers (both private and government) and must act as a catalyst for private investment for scaling the technologies downstream.

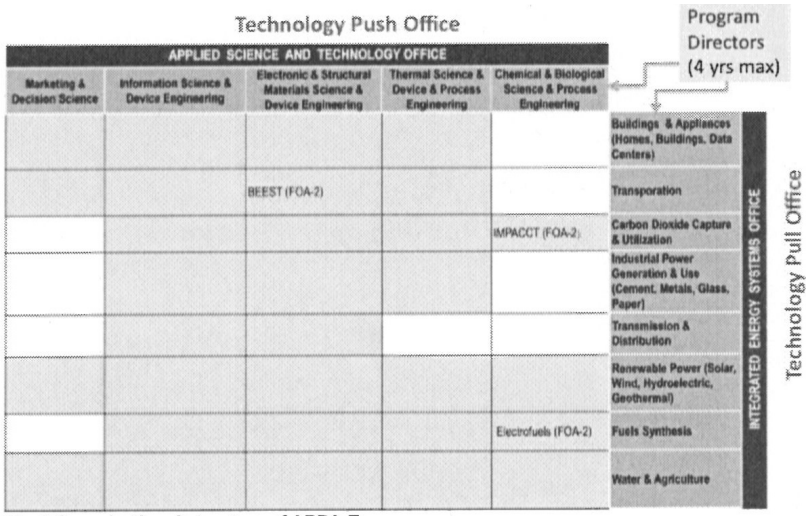


Fig. 6 Organizational structure of ARPA-E.

6.1 ARPA–E Program Organization: Figure 6 shows the program organization of the ARPA–E. The goal here is to break down silos. It is a matrix organization with two offices—Applied Science and Technology Office (or the Technology Push Office) and the Integrated Energy Systems Office (or Technology Pull Office). The Program Directors will be responsible for either a Technology Push Program or a Technology Pull Program, i.e., they will sit on the periphery of this matrix. The matrix structure is created in order to foster debate and discussion when a FOA for a program is created. For example, if a Program Director from the Technology Push Office wants to create a program FOA, he/she needs to convince the Program Directors in the Technology Pull Office that the device or process will be useful for a system. On the other hand, if a Program Director in the Technology Pull Office wants to create a program, he/she needs to integrate across disciplines in the Technology Push Office. As an example, Figure 6 shows the three FOA–2s at the intersection of Technology Pull and Push Offices. I believe the tension and constructive debate that such an organization creates is healthy, and will lead to much more collaboration and interactions between various disciplines.

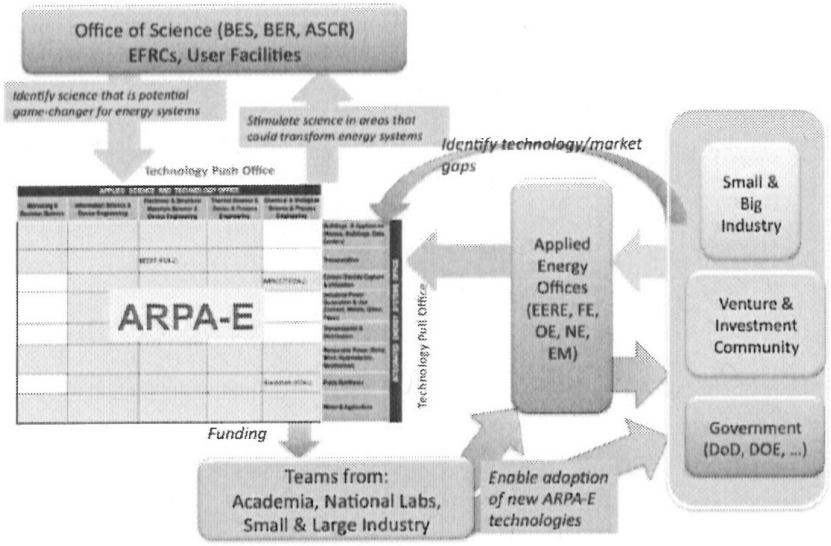


Fig. 7 Coordination of ARPA-E within DOE.

Figure 7 shows the coordination of this organization structure within the DOE. The Technology Push Office interacts with the Office of Science, such that if a discovery is made that could have significant impact on energy systems, ARPA–E would be ready to accelerate technology development based on the scientific discovery. On the other hand if science is missing in a certain energy-related area, ARPA–E could inform Office of Science to pursue the underlying science. The Technology Pull Office will interact with the Applied Energy Offices to identify technology and market gaps. The Technology Pull Office will also interact directly with small and large industry, the venture and investment communities, as well as government agencies. Based on all these input, programs will be created and teams will be funded. These teams will then create technologies, which could be adopted via leveraging the deployment programs within the Applied Offices, or directly by the industry, investment community, or government.

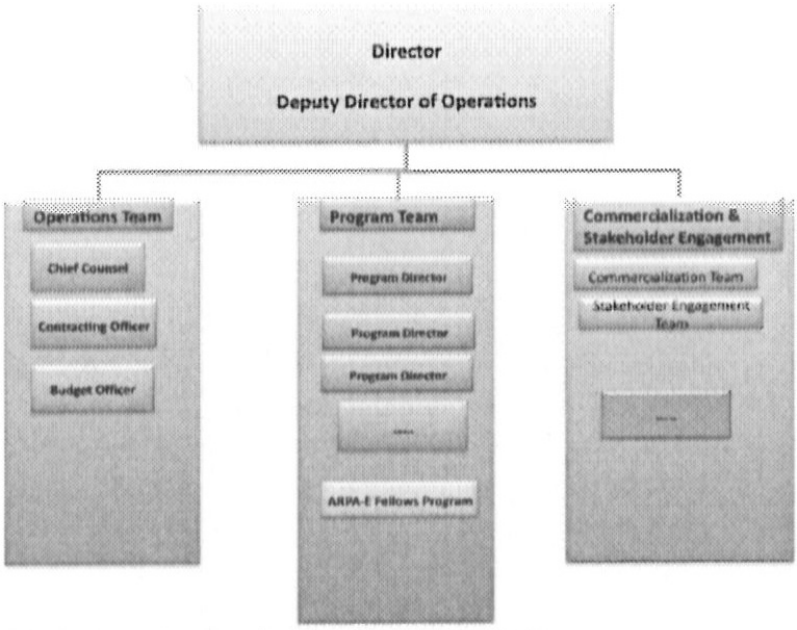


Fig. 8 Organizational structure of ARPA-E

6.2 ARPA–E Organization Structure: Figure 8 shows the organizational structure of ARPA–E. It has three teams that work collaboratively—the operations team, the program team, and the commercialization/stakeholder engagement team. All personnel report to the Director and Deputy Director of Operations.

Currently, ARPA–E is relatively small in size, and this organizational structure will suffice. As the size grows, the structure will evolve as well, and I look forward to returning to this committee with updates and requests for suggestions as this evolution continues.

6.3 Program Directors: The selection of program directors is critical to the success of ARPA–E. The people I am currently recruiting are those that have one foot in science (active researchers) and the other foot in technology development and business. These include people from academia or national labs who are very active in research, and may have started businesses or worked closely with industry, or people from the industry who are still involved in science research.

6.4 ARPA–E Fellows Program—Leveraging Our Strength: There is a grassroots movement in the U.S. where the youth have broken barriers between science, engineering, business, law, and public policy and have come together to work in energy. To tap into this body, we have created the ARPA–E Fellows program. This program will bring the best and brightest to ARPA–E, and have them serve the Nation for a maximum of two years. During this time, they will be an internal think tank to step back from our current programs and identify new ways of creating technologies that can have gamechanging impact on our and the world's energy economy.

7. Role of ARPA–E in the Energy Innovation Pipeline

ARPA–E will invest in high-risk/high-payoff technologies which could be potential game-changers. However, ARPA–E investments will be upstream in the whole development process. For these technologies to scale in volume/size and also in cost, it is important to understand the downstream process as well, and identify mechanisms to create a market pull or reduce the risk for further large-scale investments. Figure 9 shows a conceptual plot of the DOE portfolio and private investment instruments. For ARPA–E to be successful, it is important ARPA–E understands, utilizes, and facilitates technology transition in this landscape.

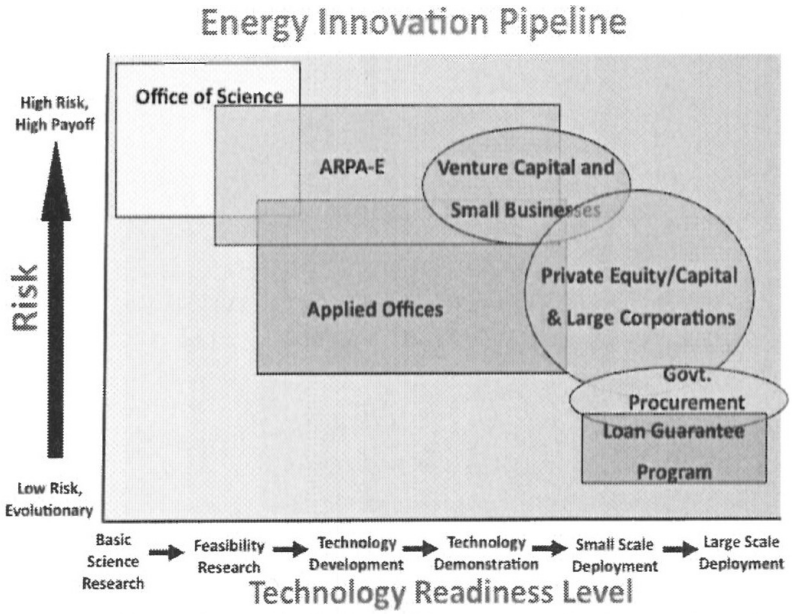


Fig. 9 Energy innovation pipeline in terms of risk versus technology readiness levels with DOE and private investments

It is also important to note that Figure 9 does not apply to all technologies. For centralized technologies, such as carbon capture or power plants, one needs to have demonstration projects that show both technical and economic performance before the risk is sufficiently reduced for large investments. On the other hand, decentralized energy technologies (e.g., batteries for vehicles) may follow a different route and therefore need not be limited by large demonstration projects.

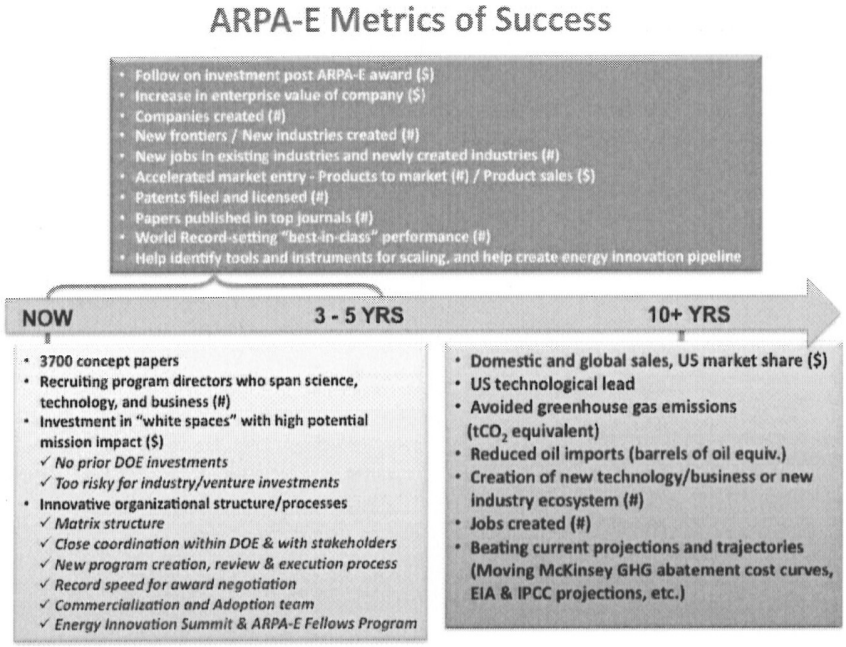


Fig. 10 ARPA-E metrics of success and timeline

8. Metrics of Success

Since the authorization of ARPA–E, there have been high expectations for its success. It is important for us to manage these expectations. In the energy sector, home runs are rarely hit in a couple of years. Therefore, it is important for us to define the metrics of success as a function of time. Figure 10 shows three stages in time. It is relatively easy to show some element of success now, which is listed in the figure. It is unlikely that the true impact of a technology can be felt in less than 10 years. But it is relatively easy to define success 10+ years from now—if an energy technology is truly game-changing, then it will have a major impact on the market, on people, on jobs, and various other metrics listed in Figure 10. Perhaps the most difficult metrics of success are in the next 3–5 years. The metrics listed in Figure 10 in this time period are what we can demonstrate in the near future. We will keep track of these metrics in a quantitative fashion and I will be happy to share them with Congress from time to time.

9. Beyond the Recovery Act

As I noted earlier, we have a plan in place to spend the Recovery Act funds allocated to ARPA–E. Once those funds are exhausted, we must continue to invest in high-risk, high-reward technologies in order to achieve major breakthroughs in energy like those I highlighted at the beginning of my testimony. I look forward to working with the Members of this Committee and many others going forward in order in order to allow Congress' vision for ARPA–E to reach its full potential.

Again, I thank you for the opportunity to testify before this Committee, and I am happy to answer any questions you may have at this time.

BIOGRAPHY FOR ARUN MAJUMDAR

Dr. Arun Majumdar became the first Director of the Advanced Research Projects Agency–Energy (ARPA–E), the country's only agency devoted to high-risk/high-payoff transformational energy research and development, in October 2009.

Previously, Dr. Majumdar was the Associate Laboratory Director for Energy and Environment at Lawrence Berkeley National Laboratory and a Professor of Mechanical Engineering and Materials Science and Engineering at the University of California, Berkeley. Dr. Majumdar is a member of the National Academy of Engineer-

ing, and has served as an advisor to the National Science Foundation, Department of Energy's Basic Energy Sciences, and on nanotechnology to the President's Council of Advisors on Science and Technology.

Chairman GORDON. Thank you, and Dr. Vest, you are recognized.

STATEMENTS OF DR. CHUCK VEST, PRESIDENT, NATIONAL ACADEMY OF ENGINEERING

Dr. VEST. Mr. Chairman, Members of the Committee, thank you very much for the——

Chairman GORDON. Use your microphone. It will work better. There we go.

Dr. VEST. Technology weakness here. I am very honored and pleased to be able to be here to comment briefly on ARPA–E this morning. As President of the U.S. National Academy of Engineering and particularly as a Member of the Committee so ably chaired by Norm Augustine, that wrote the report, *Rising Above the Gathering Storm*.

As all of you know, this Nation faces an energy crisis of immense magnitude. We have to not only meet our challenges of energy security but we also have to recognize the enormous worldwide markets that are out there if we are to become, here in the United States, the technology leaders in new green technologies.

Rising Above the Gathering Storm, as you know, broadly addressed what the Nation needs to do to remain technologically competitive and to build a strong economy for the future. Our committee proposed only one new government entity in that report, and that is ARPA–E. And I would like to explain why and take a quick read of how ARPA–E is getting started within that framework.

As you know, in the 1950s and '60s, this Nation also faced enormous challenges of unprecedented magnitude, mostly having to do with our national security. Today we have strong security, we have stealth technologies, and we won the Cold War; but we also have an IT industry, an information technology industry that dominates the way the world works today, economically and in business terms. Much of the reason we have such things was the creation of DARPA, the Advanced Research Projects Agency in the Department of Defense. It had a goal of bringing new players to the table with new ideas and a lean, flat, aggressive organization to conduct the kind of research and development that was not being done within the government, that was not being done within the traditional defense industries, and look what it brought us.

The *Gathering Storm* committee believed that we needed to take a similar step relative to the energy challenges that the United States faces. We believe that we allowed—certainly I can speak from the academic community—after the early '80s, we really allowed energy for two decades to become sort of an academic backwater. We were not attracting the best and brightest young men and women into thinking about energy research. Fortunately over the last two or three years, this situation is beginning to reverse dramatically, and we hope that ARPA–E will enable it to do so even more.

So the concept that the *Rising Above the Gathering Storm* committee had for ARPA–E is very simple, very straightforward. We

believe that we need a new organization to conduct research and development outside the traditional set of players in both government and industry, that its mission would be to conduct high-risk but potentially very high-payoff research and development associated with energy, that these projects should be clearly goal-oriented, and that they would attract new players, new players particularly from the academic community and from the entrepreneurial community that is so critical to the U.S. economy, players who would not be involved with energy otherwise. We believe that the organization should be nimble, flat, and like the original ARPA would succeed only to the extent that it could attract to Washington very bright young men and women for relatively brief periods of time in their career, not to become consumed by the traditional bureaucracy, but to run nimbly and to have the ability to make tough decisions of two kinds: one, to provide sustained support to high-risk, high-payoff, goal-oriented projects that are going well, and secondly, to be able to cut them off if they are not. Not to pander to my good colleague here, but the fact is that were it not for this energy crisis and this opportunity, Arun Majumdar would probably be happily back in Berkeley doing very fundamental academic research of the small project nature. But first within the UC system and now within the Federal Government, he has answered the call, and we need to give him the tools to bring other such people to this, to fight this great crisis that we face.

As discussion goes on, I will try to make some other comments about where we are, but let me just say simply that while the National Academies has not formally assessed what is happening to this point in ARPA–E, simply looking over the nature of the projects funded in the first round, the nature of the call for those projects, and the kind of people who are coming to the table to bring their talent and toolkits to the Nation's energy challenge, I think they are off to a great start. The key is enabling ARPA–E to stick to its mission, to distinguish itself from the other elements, more traditional elements of energy R&D, and to build the great ties into our industries, particularly our entrepreneurial sector that are needed.

Thank you very much for this opportunity.

[The prepared statement of Dr. Vest follows:]

PREPARED STATEMENT OF CHUCK VEST

I am Charles Vest, President of the National Academy of Engineering and former president of MIT. The National Academy of Engineering is an elected body of 2,000 of the nation's most accomplished engineers from industry, academia, and government. We are charged by the Congress to serve as the key external advisors to the Federal Government on matters of engineering and technology. Together with our sister organizations, the National Academy of Sciences and the Institute of Medicine, we comprise the National Academies.

Thank you for the invitation to reflect on the early stages of the establishment of the Advanced Research Projects Agency–Energy (ARPA–E), the agency's progress to date, and its promise for filling an important gap in the nation's array of tools for energy research, development and innovation. This morning I would like to recap some of the key ideas motivating the creation of ARPA–E and note how those ideas were reflected in the 2007 *America COMPETES Act* and now, in the Department of Energy's implementation of ARPA–E. Finally, I would like to offer some thoughts on how the intended features of ARPA–E might be preserved and nurtured as this new agency continues to mature.

Conceptual Foundations of ARPA–E

In 2006 I was privileged to serve on a National Academies committee chaired by Norm Augustine that produced the report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. That report included many recommendations for rebuilding the nation's ability to utilize technology innovation as an engine for economic growth and international competitiveness, but it included only one recommendation to create a new government organization, ARPA–E, similar in design and intent to the very longstanding Defense Advanced Research Projects Agency (DARPA).

The Gathering Storm committee found a serious lack of either government or industry mechanisms for exploring long-term, high-risk, but potentially very high payoff energy research, development, and innovation directed specifically toward deploying new energy technologies. The committee concluded that creation of an ARPA–E was important to develop a base of "transformational research that could lead to new ways of fueling the Nation and its economy." ARPA–E's mission would, in the committee's view, complement but not replace other mechanisms in the nation's energy R&D portfolio.

In particular, the Gathering Storm committee believed that a key reason to establish ARPA–E in the Department of Energy (DOE) was to attract and enable new elements of the scientific and engineering research and development communities from industry and academia to conduct high-risk, high-payoff, goal-oriented research that would not be carried out otherwise. The committee reasoned that ARPA–E should be a new entity that would support work outside the traditional venues such as the DOE laboratories. It would attract new players in universities and private industry, especially entrepreneurial enterprises. Key to its success would be how well the agency manages to gather bright project managers to conceive, stimulate, and fund non-traditional, potentially high-payoff, goal-oriented R&D. The general framework provided by DARPA could help provide a time-proven point of departure for rapidly designing and deploying a lean, assertive organization with a high probability of being very important to the nation's energy future.

As an educator and a long time observer of the science and engineering communities, I note that, on the whole, in recent decades few of our most creative minds were attracted to energy research. We in universities, after the early 1980s, allowed energy to slip into academic backwaters. Neither our energy companies, nor our national laboratories, nor the entrepreneurial community applied the intellectual and financial attention the area deserved. With notable exceptions, we grew complacent while a monumental national and international challenge developed.

In the last three or four years, of course, the larger scientific and engineering communities have awakened to challenge of our looming energy crisis. I note that the study, *America's Energy Future: Technology and Transformation*, initiated in 2007 by the National Academy of Engineering and the National Academy of Sciences, and released last year, identified many of the key energy technology pathways essential to transforming the nation's patterns of energy supply and demand, including improving energy efficiency in buildings, transportation and industry, coal-fired electric power generation, nuclear power, renewable energy (principally in electric power generation), oil and natural gas, alternative liquid transportation fuels derived from coal and biomass, and modernization of the nation's electric power transmission and distribution grid.

The America's Energy Future study also characterized the challenges that must be addressed in developing those technology pathways and concluded that with a sustained national commitment, the United States could obtain substantial energy-efficiency improvements, new sources of energy, and reductions in greenhouse gas emissions through the accelerated deployment of existing and emerging technologies. However, mobilization of the public and private sectors, supported by sustained long-term policies and investments, will be required for the decades-long effort to develop, demonstrate, and deploy these technologies. Actions taken between now and 2020 to develop and demonstrate several key technologies will also largely determine our options for many decades to come. Further, the study committee found that it is imperative that key technology development and demonstration activities be started very soon, even though some will be expensive and not all will be successful or will be overtaken by better technologies. In order to in develop these pathways, however, we must take concerted action and make the considerable investments necessary to enlist our most talented researchers and innovators. I believe that ARPA–E could play a considerable role in accelerating some of these transformations.

The Gathering Storm committee conceived of ARPA–E as a critically important organization reporting to the DOE Under Secretary for Science with four principal 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, young researchers, and entrepreneurs.
2. Focus on creative, out-of-the-box, potentially transformational research that industry cannot or will not support.
3. Utilize an ARPA-like organization that is flat, nimble, and sparse, yet capable of setting goals and making decisions that will allow it to sustain for long periods of time those projects whose promise is real, and to cull out programs that do not prove to be productive or as promising as anticipated.
4. Create a new tool to bridge the troubling gaps between basic energy research, development, and industrial innovation. It can serve as a model for improving technology transfer in other areas that are essential to our future prosperity.

The Gathering Storm committee did not believe it should specify the organization and mission of ARPA–E in great detail. We believed that should be worked out by the Secretary of Energy and the Under Secretary for Science in rapid, but intense, consultation with experts from the scientific, engineering, and entrepreneurial communities.

In the 1950s, defense visionaries realized that the military had to reach out to new communities for the innovative technologies to counter the rapidly changing threats of the post Sputnik era. They established the original ARPA in the Department of Defense. It was enormously successful and paid great dividends to both our military and civil societies. We believed that ARPA provides the right framework on which to design ARPA–E. It is a proven model.

Capitalizing on the Vision

The 2007 *America COMPETES Act* incorporated the Academies recommendation for creation of ARPA–E and authorized its establishment. In 2009 the *American Recovery and Reinvestment Act* (ARRA) provided $400 million for ARPA–E, the formation of which President Obama announced in a speech at the Annual Meeting of the National Academy of Sciences on April 27, 2009.

Last week, Secretary Chu reflected on these efforts before the Senate Energy and Natural Resources Committee. In particular, he indicated that

> "changing the way we do business at the DOE to improve customer responsiveness and the quality of our selection of competitive grants. As an example, in order to identify the best possible reviewers for the first round of ARPA–E proposals, I wrote a letter to many of the Presidents of our research universities to ask for the names of their best scientists and engineers. We then called upon those people to help review the proposals, arguing that they should help us as part of their patriotic duty. The technical community responded heroically and we were able to review 3,700 applications, conducting over 4.2 person years of work, in a few short weeks. That fact that we could only fund 1 percent of the applications speaks volumes that additional research support would be money well spent."

Secretary Chu's characterization of the early stages of ARPA–E is certainly consistent with the Academies conceptual ideas reflected in the Gathering Storm report.

Meeting the Challenges and Preserving the Vision

The design of the initial program solicitation by ARPA–E is quite consistent with the kind of program envisioned in the Gathering Storm report. Although the Academies has not formally evaluated them, the first round of awards seems consistent with fundamental objective of exploring innovative and potentially transformative technologies that are unlikely to find traditional support. For example, a liquid metal battery that show promise for providing grid-scale electrical energy storage, a new wind turbine that can achieve higher efficiencies with a smaller size, and a new approach to carbon capture inspired by a human body enzyme are all examples from this first round of awards.

Looking forward, it is essential that ARPA–E remain faithful to the original goals of pursuing high-risk, high-payoff opportunities, staying connected and current with the vibrant community capable of carrying out ARPA–E activities, and re-tuning the portfolio of activities continuously to quickly initiate and sustain new activities and to rapidly phase out those that show less promise just as quickly. Otherwise the ARPA–E mission will merge into the balance of the energy R&D mission, re-introducing the gap ARPA–E was designed to fill.

Critics of the original conceptual ARPA–E design raised a variety of issues, including that an ARPA–E might 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. At this point in the agency's evolution, I would characterize these criticisms as potential risks, but ones that will be avoided if the new agency keeps on its current path, true to its mission, and attracts talented managers.

Perhaps a more recent challenge, not unrelated to the challenge of preservation of the ARPA–E's distinct mission, is coordination of the agency's efforts with other DOE approaches for building strong channels of innovation, such as the Energy Frontier Research Centers, which are multi-year, multi-investigator scientific collaborations focused on overcoming known hurdles in basic science and, Energy Innovation Hubs, which will establish larger, highly integrated teams working to solve identified high-priority technology challenges. I believe that with careful management and clear goals, these elements can form a productive and efficient ecosystem for energy innovation and technology deployment.

Energy is absolutely fundamental to a modern economy, but the historical patterns of energy supply and utilization in America are on the verge of changing substantially. Exactly how our energy use should or will change, and at what rate, is a very difficult and complex challenges for this generation. For over three decades America's capacity for technology innovation has been a cornerstone of our national strategies for dealing with both current and long-term energy policy issues, but the new sense of urgency has raised the stakes and the scale of the challenge. The early stages of development of ARPA–E show promise as a key component in nation's energy R&D portfolio that has been missing for many decades.

Thank you again for the opportunity to share my thoughts with you today and I look forward to addressing any questions the Committee might have.

BIOGRAPHY FOR CHUCK VEST

Charles M. Vest is president of the U.S. National Academy of Engineering and president emeritus of the Massachusetts Institute of Technology. A professor of mechanical engineering at MIT and formerly at the University of Michigan, he served on the U.S. President's Council of Advisors on Science and Technology from 1994–2008, and chaired the President's Committee on the Redesign of the Space Station and the Secretary of Energy's Task Force on the Future of Science at DOE. He was a member of the Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction and the Secretary of Education's Commission on the Future of Higher Education. He was vice chair of the U.S. Council on Competitiveness for seven years, has served on the boards of DuPont and IBM, and was awarded the 2006 National Medal of Technology.

Chairman GORDON. Thank you, Dr. Vest. Dr. Atti, you are recognized.

STATEMENTS OF DR. ANTHONY ATTI, PRESIDENT AND CEO, PHONONIC DEVICES

Dr. ATTI. Good morning Chairman Gordon, Ranking Member Hall, and Members of the Committee, thank you for inviting me to testify on an urgent matter of national importance, commercializing clean energy technologies. My name is Anthony Atti, and I am the co-founder and CEO of Phononic Devices and am deeply passionate about this issue. Originally from Buffalo, New York, I have had the uniquely American opportunity to work in clean energy across the country as a scientist and entrepreneur and am continually inspired by our entrepreneurial spirit, now very much embodied, I believe, in ARPA–E. I have an undergraduate degree in biochemistry from Ithaca College and earned my Ph.D. in Organic Chemistry from the University of Southern California where I researched hydrogen and methanol fuel cells in partnership with NASA's Jet Propulsion Laboratory. During that time our research

was supported by DARPA with an audacious goal: extend battery run time while significantly reducing their weight by more than 30 percent, thus benefiting the war fighter. Here I saw the positive impact of a transformational funding approach coupled with commercial emphasis, an important template for ARPA–E. I have now spent almost a decade building early-stage clean energy companies. The rewards are great but so too are the risks.

First and foremost is technology readiness. Few investors can quantify this variable and often misjudge time to market. Second is market risk; if you build it, the customer does not always come. And last is operating risk. Start-up companies require staffing of key management and technical positions. Collectively, a chicken-and-egg scenario confronts entrepreneurs as they are told by investors, "come see me when you have something," only to think, "but isn't that what your money is for?"

In today's energy landscape we generate most electricity by making heat, whether it is through burning coal or splitting atoms. That heat makes steam which turns a turbine and makes electricity. A somewhat antiquated process, most of the heat is wasted, a staggering 50–60 percent according to Department of Energy estimates. Consequently, and not without some irony, there is a more than $7 billion industry for refrigeration technologies that deal with the damaging effects of this heat.

Phononic Devices was founded to recapture this waste heat and convert it into usable electric power, or depending on the source of the heat, provide refrigeration and cooling. This concept, called thermoelectric, uses advanced semiconductor materials, similar to those found in microprocessors and solar cells, to manage heat by manipulating the direction of electrons at the nanoscale. Resembling computer chips, thermoelectric devices are quiet, have no moving parts or harmful emissions, and our design concepts are projected to dramatically improve thermoelectric efficiency from less than 10 percent today to more than 30 percent. This is expected to result in a dollar-per-watt energy savings of 75 percent for power generation and 60 percent for cooling, respectively.

Innumerable market opportunities for power and cooling exist. Steel and aluminum manufacturers accustomed to venting heat through smoke stacks now view this as a source of power while a new generation of refrigerators and air conditioners can operate quietly and without harmful chemicals.

While our plan is sound and the rewards truly transformational, the challenge ahead is formidable. Phononic Devices' technology is still early in development, market penetration features entrenched multi-billion dollar competitors, and we are literally building the company from the ground up out of laboratories at the University of Oklahoma and North Carolina State University. Very few venture capital investors are willing to take on this level of risk, and this economy only makes that worse. However, in the process of responding to ARPA–E's program we have made great progress with investors. We signed an exclusive agreement with the University of Oklahoma accessing valuable intellectual property, partnered with best-in-class researchers at the University of California Santa Cruz and California Institute of Technology, and built a technical and business database for investors to review.

Having now successfully concluded the reward process, Phononic Devices has raised more than $2 million in venture capital financing from clean energy leaders Venrock and Oak Investment Partners. We have aggressive growth plans. Having now added four full-time engineers in just six months, our business plan projects the need for more than 250 employees over the next three years. Already, we have received inquiries from Fortune 500 defense, industrial and electronics customers with a pressing need for innovative cooling solutions or power generation options to mitigate their electricity costs.

Our company has a very simple but important motto, "do good science, quickly," and with ARPA–E it is exciting to be a part of this important initiative benefiting our country at such a critical time in her history.

Thank you again for your time and I look forward to answering your questions.

[The prepared statement of Dr. Atti follows:]

PREPARED STATEMENT OF ANTHONY ATTI

Introduction and Background

Good morning Chairman Gordon, Ranking Member Hall, and Members of the Committee, thank you for inviting me to testify on an urgent matter of national importance; commercialization of clean energy technologies. My name is Anthony Atti and I'm the Co-Founder and CEO of Phononic Devices and am deeply passionate about this issue. Originally from Buffalo, NY, I've had the uniquely American opportunity to work in clean energy across the country as a scientist and entrepreneur and am continually inspired by our entrepreneurial spirit, now very much embodied I believe in ARPA–E. I have an undergraduate degree in Biochemistry from Ithaca College and earned my Ph.D. in Organic Chemistry from the University of Southern California where I researched hydrogen and methanol fuel cells in partnership with NASA's Jet Propulsion Laboratory. During that time our research was supported by DARPA with an audacious goal . . . extend battery run time while significantly reducing their weight by more than 30% thus benefiting the war fighter. Here I saw the positive impact of a transformational funding approach coupled with commercial emphasis; an important template for ARPA–E. I've now spent almost a decade building early stage clean energy companies; the rewards are great but so too are the risks. First and foremost is technology readiness; few investors can quantify this variable and often misjudge time to market. Second is market risk; if you build it . . . the customer does not always come. And last is operating risk; start-up companies require staffing of key management and technical positions. Collectively, a chicken and egg scenario confronts entrepreneurs as they're told by investors; "come see me when you have something" . . . only to think "but isn't that what your money is for?"

Phononic Devices

In today's energy landscape we generate most electricity by making heat, whether it's through burning coal or splitting atoms. That heat makes steam which turns a turbine and makes electricity. A somewhat antiquated process, most of the heat is wasted . . . a staggering 50–60% according to Department of Energy estimates. Consequently, and not without some irony, there's a more than $7B industry for technologies that deal with the damaging effects of this heat. Phononic Devices was founded to recapture this waste heat and convert it into usable electric power, or depending on the source of the heat, provide refrigeration and cooling. This 'thermoelectric' concept uses advanced semiconductor materials, similar to those found in microprocessors and solar cells, to manage heat by manipulating the direction of electrons at the nanoscale. Resembling computer chips, thermoelectric devices are quiet, have no moving parts or harmful emissions, and our design concepts are projected to dramatically improve thermoelectric efficiency from less than 10% today to more than 30%. This is expected to result in a $/W energy savings of 75% for power generation and 60% for cooling, respectively. Innumerable market opportunities for power and cooling exist . . . steel and aluminum manufacturers accustomed to venting heat through smoke stacks now view this as a source of power while a

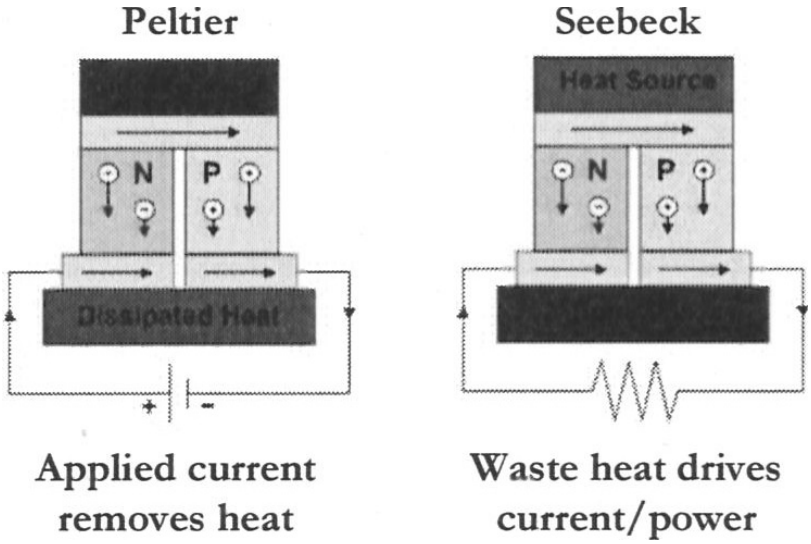
new generation of refrigerators and air conditioners can operate quietly and without harmful chemicals.

ARPA Impact

While our plan is sound and the rewards truly transformational, the challenge ahead is formidable; Phononic Devices' technology is still early in development, market penetration features entrenched multi-billion dollar competitors, and we are literally building the company from the ground up out of laboratories at the University of Oklahoma and North Carolina State University. Very few venture capital investors are willing to take on this level of risk . . . and this economy only makes it worse. However, in the process of responding to ARPA–E's program we have made great progress with investors: we signed an exclusive agreement with the University of Oklahoma accessing valuable intellectual property; partnered with best-in-class researchers at the University of California Santa Cruz and California Institute of Technology; and built a technical and business database for investors to review. Having now successfully concluded the reward process, Phononic Devices has raised more than $2M in venture capital financing from clean energy leaders Venrock and Oak Investment Partners. We have aggressive growth plans, having now added four full time engineers in just six months our business plan projects the need for more than 250 employees over the next three years. Already, we have received inquiries from Fortune 500 defense, industrial and electronics customers with a pressing need for innovative cooling solutions, or power generation options to mitigate their electricity costs. Our company has a very simple but important motto . . . "Do Good Science . . . Quickly" and with ARPA–E is excited to be a part of this important initiative benefiting our country at such a critical time in her history. Thank you again for your time and I look forward to answering your questions.

WRITTEN TESTIMONY

Company Background: Phononic Devices is commercializing advanced thermoelectric semiconductor materials and devices designed to convert waste heat from industrial and commercial processes into usable electric power, and conversely, highly efficient cooling and refrigeration. Despite the national security risks and pollution concerns associated with fossil fuel consumption, the Department of Energy estimates that 50–60% of all the energy consumed in the US per year is wasted as heat; recovery of which is an intense area of interest. Phononic Devices' unique approach and design concepts, developed in an exclusive licensing partnership with the University of Oklahoma, are projected to dramatically improve thermal to electric energy conversion efficiency by combining key thermoelectric properties: superior thermopower with thermally insulating thin film materials. With diverse energy harvesting applications that include powering wireless devices, hybridization with solar thermal concentrators and combustion engines, as well as the ability to displace compressors for residential and HVAC cooling, Phononic Devices' approach makes possible a more than $125B market opportunity.



Nanostructured Semiconductor Materials: despite a clean and reliable solid state platform and high value-add uses that include opto-electronic cooling and custom refrigeration, widespread thermoelectric commercial adoption has been hindered by low ZT ~1; an important gauge of Carnot Power Conversion Efficiency of only ~10%. Too low to compete with or displace incumbent power generation and refrigeration technologies, traditional thermoelectric design concepts have focused mainly on reducing lattice thermal conductivity with limited success. Emphases on material nanostructures that specifically optimize thermopower—core to Phononic Devices' approach—present a tremendous opportunity.

$$ZT = \frac{\alpha^2 T}{\lambda \rho}$$

α - Seebeck Coefficient
ρ - electrical resistivity
λ - thermal conductivity

Transformational Impact: High Efficiency Thermoelectric Devices: Phononic Devices is uniquely positioned to accelerate market penetration through direct sales, OEM licensing, and joint venture partnerships with industry and manufacturing leaders. Phononic Devices recognizes that to capture an existing share of the $300M thermoelectric market, but more importantly access a more than $125B cooling and energy harvesting opportunity, its product platform must radically change the fun-

damentals of thermal to electric energy conversion. Performance features far superior to existing competitors and exceeding demanding customer requirements are enabled by Phononic Devices' thin film and high efficiency thermoelectric approach. Device features will follow a modular and scalable design approach; flexible range of operating conditions; highly efficient 'Z'T Carnot Power Conversion and COP cooling; and a thin-film manufacturing platform readily scaled and transitioned using industry-standard high volume throughput manufacturing techniques. Phononic Devices is led by an experienced entrepreneurial team, best-in-class technical collaborators, and backing from top tier Silicon Valley Cleantech investors; the company was recently recognized by the newly created ARPA–E as a leader in the emerging clean energy marketplace.

MARKET OPPORTUNITY

Cooling & Refrigeration: thermoelectric cooling is popular for luxury and recreational refrigerators and also widely used to cool and control temperature in opto-electronics and telecommunications equipment. Concerning the former, as customers increasingly incorporate aesthetics into their utility purchases, a quiet and more importantly compact option provides greater flexibility and functionality beyond the kitchen. In the latter case of opto-electronics and telecom, cooling and temperature stabilization of laser diodes, superluminescent laser diodes, and diode pumped solid state lasers is of paramount importance. In many cases thermoelectric modules are considered a standard component of laser devices as temperature control is a critical element needed to maintain laser lifetime, prevent premature failure, and enable advantageous laser emission parameters.

Opportunity	IT Server Cooling	Refrigeration	Commercial HVAC
Reduce Emissions (Conservative Estimates)	• 71% reduction in electricity vs. cooling fans • 84,000 tons of CO_2 eliminated • 70,350 tons of coal not burned	• 60% reduction in cooling power vs. compressors • 54,400 tons of CO_2 saved • 26,760 tons of coal not burned	• 33% reduction in cooling power vs. compressor • 130,000 tons of CO_2 saved • 16MM tons of coal not burned
Market Opportunity	• 35M servers worldwide by 2012, 15% CAGR	• 16M refrigerators sold annually in US; 2% CAGR • Custom refrigeration CAGR of 7%	• >15M HVAC sold per year in US; 3.2% CAGR • HVAC global equipment demand $84B; 6% CAGR

Energy Harvesting: energy harvesting is the process whereby ambient heat is captured, converted into electricity and used to drive electrical and combined devices. The use of thermoelectrics, in which a temperature difference creates an electric potential, can convert a portion of this waste heat from thermal sources into electricity thereby improving the overall efficiency of an operating system. Widely used in space propulsion for decades, recently thermoelectric generators have been targeted by military and wireless customers for sensors and remote power where battery life and access to back-up power is problematic. Hybridization with Concentrating Solar and Concentrating PV are also of great interest as waste heat from the sun's direct rays can be captured to augment the collective power and efficiency of the installation.

Opportunity	Solar Hybridization	Wireless Devices	Automotive Waste Heat Recovery
Reduce Emissions (Conservative Estimates)	• Eliminates 480,000 tons of CO_2 & 402,000 tons of coal	• Eliminates 1,900 tons of batteries from landfill • TE device reliability > 15 years	• 13% improvement over current fuel economy (28 vs. 25 mpg) • Eliminate 58MM tons of CO_2 & 166MM bbls crude
Market Opportunity	• $/Wp: 50% cheaper than current PV systems • Cost competitive w/grid	• $67BB RFID tags expected by 2014 • 50B battery market; $10B for micro power devices	• More than 8MM mid & full-size sedans purchased annually in US

BIOGRAPHY FOR ANTHONY ATTI

An experienced clean energy investor and entrepreneur, Dr. Atti has demonstrated expertise and leadership in venture financing, business development, start-up growth and operations, and negotiating joint venture relationships. As a former Director at MHI Energy Partners, a seed and early stage energy private equity fund, Dr. Atti managed deal flow networks, conducted due diligence, structured venture financing transactions, and provided direct portfolio company leadership as an Entrepreneur-in-Residence. Dr. Atti earned his Ph.D. in Organic Chemistry from the Loker Hydrocarbon Research Institute at the University of Southern California under the direction of Dr. G.K. Surya Prakash and Dr. George A. Olah; the former a world-renowned fluorine chemist and the latter a winner of the 1994 Nobel Prize in Chemistry. As a PostDoctoral member of the Electrochemical Technologies team, he conducted research on hydrogen and methanol fuel cells at the NASA–Jet Propulsion Laboratory in Pasadena, CA. Dr. Atti also holds an MBA from New York University and a Bachelor of Arts in Biochemistry from Ithaca College.

Chairman GORDON. Thank you, Dr. Atti. Mr. Denniston, you are recognized.

STATEMENTS OF MR. JOHN DENNISTON, PARTNER, KLEINER PERKINS CAUFIELD & BYERS

Mr. DENNISTON. Good morning Chairman Gordon, Ranking Member Hall, Members of the Committee. I am grateful for the chance to support your vital work in helping America compete and the race for new, clean energy technologies.

The venture capital community is keenly interested in the green tech sector. In recent years, venture capitalists have backed many breakthrough projects in this field, some of which are already helping to transform the global energy industries. In fact, it would be hard for me to overstate the opportunity we see unfolding in the energy and transportation sectors, collectively, the world's largest at $6 trillion annually.

Major recent technical advances and the early benefits of economies of scale have significantly narrowed the price gap with fossil fuels, and this process is only bound to speed up with further innovation.

What all this means is that we are now in the midst of a new industrial revolution holding the promise of vast numbers of new jobs from blue collar, builders, factory and maintenance workers, to

white collar engineers, salespeople and managers. The question is, where will these jobs be based? Unfortunately, the United States has already fallen behind in the global green tech competition. Here is an alarming example. Today the United States is home to only two of the world's top 10 solar companies, two of the world's top 10 wind turbine manufacturers, and only one of the world's top 10 advanced battery makers.

Summing up, we have a paltry 17 percent market share of the leading companies in these critically important growth industries, and we face a particularly strong economic threat from China where the central government has decided that renewable energy is mission critical to their future. Chinese officials are making huge investments in research and development while their state-owned banks are now bankrolling green exports, a brilliant means of deploying their foreign exchange reserves as a competitive weapon at a time when the rest of the world is short of cash.

The results have been staggering. For example, within just a few years, China has built its solar industry basically from scratch to become the largest in the world. Within three years, it increased its market share of the global solar panel market from two percent to nearly 50 percent. During that same period, U.S. market share went in exactly the opposite direction, from 43 percent to 16 percent.

The global competition is daunting, but it is unfortunately far from our only concern. Time is running out for America, along with the rest of the world, to combat the risks of climate change. We are morally obligated to invent a safer world for our children and their children.

Now, ARPA–E's great promise is to deliver the clean energy breakthroughs that are so vital to our economy, our standard of living and the environment. It can do this mainly by addressing the dangerous deficiency of renewable energy projects at U.S. scientific institutions. U.S. renewables researchers lack neither the technical talent nor the passion, but they unfortunately do lack the funding. And what this means, to use a baseball metaphor, is that America simply isn't getting enough at-bats, even as our global competitors are making the necessary investments to continue hitting home runs.

ARPA–E promises to do for U.S. green tech what its successful predecessor, DARPA, has done not only for our military but also for the private sector, including the creation of the internet, global positioning satellite, robotics, lasers and so many others.

I have been pleased to watch ARPA–E's fast, effective work in selecting its first 37 grantees. As I review the list of these high-risk, high-reward projects, I am heartened to see how many aspire to tackle today's most urgent energy challenges. Indeed, ARPA–E appears to be on the road to duplicating DARPA's success except that, unlike DARPA, ARPA–E's funding and status are uncertain. That is really why I am here today, to urge you to extend the Agency's charter and expand its resources. ARPA–E should not be treated as a short-term experiment but rather as a pillar of U.S. energy policy. Only then can America show the rest of the world once again how to lead an industrial revolution.

[The prepared statement of Mr. Denniston follows:]

PREPARED STATEMENT OF JOHN DENNISTON

Introduction

Good morning, Chairman Gordon and Members of the Committee. My name is John Denniston, and I'm a partner at Kleiner Perkins Caufield & Byers, based in California's Silicon Valley. Founded in 1972, Kleiner Perkins is one of America's oldest and most successful venture capital firms.

Our mission at Kleiner Perkins is to recognize emerging technology and market trends. We've funded more than 575 start-up companies over the years, backing entrepreneurs who have introduced innovative advances in such vital growth industries as information technology, medical products and services, and telecommunications. More than 170 of our companies have gone public, including Amazon.com, AOL, Compaq Computer, Electronic Arts, Genentech, Google, IDEC Pharmaceuticals, Intuit, Juniper Networks, Millennium Pharmaceuticals, Netscape, Sun Microsystems, Symantec and VeriSign. Our portfolio companies collectively employ more than 325,000 workers, and generate $125 billion in annual revenue. My testimony today reflects my own views.

I'm honored to be here today and grateful for the chance to support your vital work in helping America compete in the global race for new energy technologies. The creation of ARPA–E—the Advanced Research Projects Agency–Energy—marks major progress in this increasingly fierce competition. As you know, ARPA–E was modeled after DARPA in the Department of Defense, which has brought us not only cutting-edge military technology, but also life-changing commercial advances through the Internet, global positioning satellites, robotics, and lasers. ARPA–E's great promise is to deliver critically important breakthroughs in clean energy, which will benefit our economy, our standard of living, and our environment.

The Second Industrial Revolution

The world today is in the midst of a major economic transition that in many ways resembles an earlier historic turning point. In the Industrial Revolution, humans traded the power of horses and wood for mass-produced coal and oil, thereby unleashing a cascade of new technologies, from mass-manufacturing methods to railroads, automobiles, electricity, and telephones. These new means of extracting and harnessing fossil fuels enabled virtually all of the other innovations of that era, and thus catalyzed what was arguably civilization's most profound transformation up to that time, from an agrarian society to an industrial one. In that sense, the Industrial Revolution might more accurately be thought of as the world's first Energy Revolution.

Today, history is repeating itself, as the triple threat of climate change, global competition and energy insecurity chases America into a new industrial transformation—in this case, with clean, green technologies replacing the dirty brown ones. It's a time, once again, of creative destruction: an idea popularized by the economist Joseph Schumpeter, which holds that longterm economic growth is achieved through continual innovation by entrepreneurs, who constantly replace incumbent companies and industries with new and better ones.

The Innovation Imperative

Today, as in the Industrial Revolution, our ability to discover new answers for old questions will determine our continued prosperity. In other words, technology innovation continues to be the secret sauce of America's robust economy.

Consider: in recent decades, our high-tech industries have accounted for a relatively modest portion of our overall economy—less than 10 percent of gross domestic product. Yet these same industries have continuously generated fully half of all economic growth and three-fourths of productivity gains. And of course, it is GDP and productivity growth that create dynamic job opportunities and rising standards of living.

Today, throughout the world, we're seeing a burst of inventive and entrepreneurial activity in "greentech"—technologies aimed at helping the environment as well as the economy. Innovators have recently made enormous technical advances across a range of disciplines—electronics, physics, chemistry, biology, and new materials—which have narrowed the price gap with fossil fuels. And this process is only bound to speed up, as the costs of renewable energy continue to decline with further innovation and economies of scale.

A key distinction between renewable and fossil energy is that the renewable fuels themselves—sunlight, wind, ocean waves, and the earth's heat—are free. Unlike coal or oil, these free, clean, sources of power are both abundant and invulnerable to both the disruptive price volatility of the commodity markets and the prospect

of increasing environmental compliance costs. All they require of us is that we figure out cost-effective ways to harness them. And we're making swift progress in this regard.

Solar power offers an excellent example of the ability of innovators and the power of economies of scale to drive down cost: As entrepreneurs have sprinted into this sector, solar module prices declined nearly 50 percent last year alone. Experts predict further significant price declines going forward. In contrast, crude oil prices increased 100 percent last year, and are up by roughly 300 percent over the past decade.

The Risk of Inaction

One of our great blessings as Americans is that we're a nation of innovators. This explains why we still lead the world in the information technology and life science industries. What worries me, however, is evidence that we are rapidly falling behind when it comes to clean energy.

In the last Industrial Revolution, America faced very little competition outside of England, and the word "globalization" wasn't even in our vocabulary. Today, from Ireland to India, dozens of nations have discovered the recipe for our secret sauce, and are racing to innovate their way to new jobs and prosperity. Some are already enjoying extraordinary success—gains, I'm sorry to say, that have come at our expense.

We face a particularly strong economic threat from China, where the central government has determined that renewable energy is mission-critical to its future, and has aggressively rolled out ambitious policies and huge investments to support it. Chinese officials have granted subsidies, free land, and cash for research and development. The nation's state-owned banks are also bankrolling green exports, a brilliant means of deploying its foreign exchange reserves as a competitive weapon at a time when the rest of the world is short of cash.

The results of these policies have been staggering. Within just a few years, China has become a global leader in the solar, wind, and advanced batteries industries. In the solar industry, it has built an industry basically from scratch to become the world's largest manufacturer. Three years ago, China held merely two percent of the solar panel market; by the fourth quarter of 2009, that share had grown to nearly 50 percent. During the same period, U.S. market share in this sector declined from 43 percent to 16 percent.

We can't sit back and watch these numbers continue to decline. The large and growing global solar photovoltaic market now exceeds $40 billion annually, already surpassing the size of the global internet search market.

And let me remind you that solar power is only one sector in what is by far the world's largest and arguably most essential set of industries: the $6 trillion energy and transportation markets. These markets are on the cusp of a dramatic transformation, which translates to the kind of economic opportunity seen only every several generations or so. We simply cannot afford to ignore them.

The Climate Crisis

As if globalization weren't a daunting enough threat, it's not by any means all we have to worry about. We simply can't forget, as much as it may be human nature to try, the mounting risks of climate change. Some of the world's leading scientists have determined that 350 parts per million is the safe upper limit for carbon dioxide in our atmosphere. We passed that benchmark back in 1988, and are rapidly approaching 400, a level that threatens dangerous weather, serious floods, disruptions in food supply, and increased epidemics. Put simply, climate change has become our most urgent innovation imperative: we're morally obliged to invent a safer world for our children and their children.

The Promise of ARPA–E

ARPA–E is a bold and brilliant effort to support innovation in the greentech industries that hold such promise both for our standard of living and the future of our planet. Once again, I commend this Committee for its pioneering achievement in creating this new agency. I'll now address the four questions that accompanied my invitation to speak here today.

Venture Capitalists, Greentech, and ARPA–E

You've asked me to describe the role of venture capital in energy technology development and give my thoughts about how ARPA–E might complement that role.

Venture capital's role in the energy markets compares with the one it has played for decades in the information technology and life sciences industries. Typically,

venture capital firms seek to invest in companies that have moved beyond their earliest, highest-risk technical phase. The private sector as a whole largely avoids basic research, and venture capitalists are no different in this regard.

In contrast, the Federal Government has historically and successfully funded very early-stage research, and thus played an instrumental role in the innovation chain in a host of industries, including information technology, the life sciences, and national defense. In fact, through some remarkably successful partnerships with research universities and the private sector, which licenses commercialization rights for products that have demonstrated value, the government has provided the vast majority of basic research funding in this country. These public-private partnerships have saved millions of lives and generated hundreds of billions of dollars in revenue in the life sciences, while creating massive new information technology industries.

The great opportunity with ARPA–E is that this new agency can now play a similar role in U.S. energy technology development by providing that desperately needed, early-stage funding for breakthrough renewable-energy technologies. ARPA–E funding can also help address our competitive and environmental challenges by enabling companies to speed up production of breakthrough technologies and pursue new ones.

ARPA–E can perform this role most effectively, complementing the role of investors and scientists, if it is structured as a long-term initiative, with an expanded budget and clearly defined focus on renewable energy. In these ways it would truly mirror its tremendously successful predecessor, DARPA.

DARPA pioneered what's known as translational research, in which the research sponsors first identify the most crucial market requirements, and only after doing so, provide funding for the most worthy and promising technologies. DARPA achieved its phenomenal success not by seeking to avoid surprises, but by aspiring to create them. It served as a catalyzing force by defining the challenges, working with researchers to develop solution concepts, and building a community of change-agent advocates. DARPA's translational research approach embraces risk, seeking to ignite revolutionary breakthroughs rather than merely incremental improvements in existing products. The risks may be big, but as history has demonstrated, so are the potential rewards.

In the energy industry today, we face many enormous challenges. How can we limit the amount of greenhouse gases escaping from conventional power plants? How can we make intermittent sources of power, from wind or the sun, more cost-effective and reliable? What are the best technical approaches to achieve high-performance, low-cost batteries for both transportation and grid storage? What policies should the Federal Government adopt to assure America leads the next industrial revolution? ARPA–E represents an essential first step in addressing these and other urgent questions.

The U.S. Greentech Investment Climate

I last addressed the issue of the climate for greentech investment in my testimony before the House Subcommittee on Energy and the Environment in April 2007, on the eve of the global financial meltdown. The industry faced impediments then, and today, as may come as no surprise, the situation is even more challenging.

The good news is that the venture capital community is keenly interested in this sector, and eager to invest in promising green technologies. In recent years, venture capitalists have invested in many breakthrough green technologies, some of which have already entered the marketplace, and others which will come to market in the near future. I'm confident these companies, taken as a whole, have begun a dramatic transformation of our energy system, green for brown.

Unfortunately, however, U.S. green entrepreneurs and their venture sponsors are encountering obstacles in the form of the financial crisis, a scarcity of renewable energy projects in U.S. research laboratories, and fierce competition from abroad.

The venture industry, like virtually every other industry, has been hit hard by our economic crisis. In 2009, new investor commitments to venture capital firms declined nearly 50 percent over the previous year. The number of venture firms able to raise funds fell to its lowest point last year since 1993. Further, the scarcity of capital across the board—in particular in the credit markets—has imposed a new, major obstacle in the path for renewable energy entrepreneurs.

Total venture capital spending on greentech projects last year amounted to approximately $5 billion. While that may initially seem like a large figure, it represents a decline relative to 2008 funding, and, more importantly, a tiny fraction—less than three-tenths of one percent—of the $1.8 trillion U.S. market for energy and transportation. This three-tenths of one-percent, moreover, constitutes the lion's share of U.S. private sector renewable-energy research and development investment, since, as a rule, large energy companies have not been investing signifi-

cant funds in R&D for renewable energy. And, unfortunately, if you show me an industry investing less than three-tenths of one percent of its revenue on research and development, I'll show you an industry that's not preparing for the future.

I must emphasize here that, to date, this lack of private investment in green energy R&D has not been made up by public sources. While the Federal Government has provided massive direct and indirect subsidies and benefits for the fossil fuel and nuclear industries over the last several decades, it has afforded only scant support for green energy technology research. In the years leading up to the creation of ARPA–E, the Federal Government provided little more than $1 billion annually for all non-nuclear, clean and renewable energy research. In the health care sector, in contrast, the National Institutes of Health has annually provided approximately $30 billion in research funding.

The main result of the big greentech R&D deficit is a conspicuous shortage of renewable energy research projects at American universities and national labs. It's not due to any lack of technical talent or interest among researchers to invent breakthrough greentech products. To the contrary, American universities and our national labs are loaded with world-class scientific and engineering talent, many of whom are eager to devote their life's work to greentech research. To date, however, they've been held up by a lack of support for early-stage research. What this means for investors, to use a baseball metaphor, is that we simply aren't getting enough at-bats, even as our global competitors are making the necessary investments to continue hitting home runs.

A final challenge facing the American greentech investment community and entrepreneurs—one that is rapidly becoming a threat to the U.S. economy as a whole—is the fierce competition coming from overseas. Here's an alarming example: Today, the United States is home to only two of the world's ten largest solar companies, merely two of the world's top ten wind turbine producers, and just one of the top ten advanced battery manufacturers. Summing up: only one-sixth of these 30 top renewable energy companies are now based in this country. That's a paltry 17 percent market share.

The momentum in this industry is rapidly moving outside our shores, and the bottom line is that America must either start investing a lot more today to build leadership in these new industries and jobs, or we can continue with business as usual and end up buying windmills from Europe, batteries from Japan and solar panels from China.

ARPA–E's Performance

All I've said up to now may help explain why my colleagues and I are so hopeful about ARPA–E. And all that we've seen to date of this remarkable agency has raised our hopes even more. ARPA–E is no panacea, but it does begin to address America's deficit in high-risk, high-reward renewable energy research projects.

Commendably, you've designed the agency to mirror the successful traits of its worthy predecessor, DARPA. Like DARPA, ARPA–E is small, nimble, and to all appearances unafraid of risk, with a flat, non-hierarchical management structure. It clearly has ample cabinet-level sponsorship and support, with its new chief, Dr. Majumdar, reporting directly to Secretary Chu. Within just a few months of his appointment last September, Dr. Majumdar has already come up with the creative idea of a new Fellows program for recent doctoral graduates.

ARPA–E has made fast, impressive work of selecting its first 37 grantees from an initial pool of 3,600 applications. As I review the list of these high-risk, high-reward projects, I'm heartened to see how many of them are aimed directly at tackling many of today's most urgent energy challenges. These include work on batteries for grid storage, which will assure a stable electrical grid even as we ramp up our supplies of clean but intermittent power sources from the sun and the wind. There's also funding for transportation batteries, which will accelerate the advent of electric transportation. Several other grantees are working on the urgent task of limiting greenhouse gas emissions from conventional, fossil-fuel power plants. Yet another project focuses on improving building efficiency, saving the vast amounts of energy that today are literally going out the window.

ARPA–E's list of winners also showcases the kinds of partnerships we need to most efficiently ramp up new energy technologies. University researchers are joining entrepreneurs and government managers to transform today's good ideas into tomorrow's mass-produced solutions. These are all terrific models of how to mobilize America's inventive talents.

ARPA–E, Job-Creation and Technological Competitiveness

As I've noted, the United States today remains a world capital of innovation. But we can't take our long-standing technology dominance for granted. Remember, today only one-sixth of the world's top solar, wind and advanced battery companies are based in the United States.

Ask yourself: what if only one of the six top information technology companies were American? What if Microsoft were German, Apple were Japanese, and Google, eBay and Yahoo were Chinese, and only Amazon were based in this country? We'd be sending billions of extra dollars and hundreds of thousands of jobs overseas, to support other nations' economic growth.

Unfortunately, this is just the situation we have shaping up in the renewable energy industries—the ones that will surely drive the second industrial revolution.

Our competitors offer us a daunting challenge. Yet I doubt anyone here in this room is ready to concede this race. In fact, our purpose today is to chart a course to guarantee America's position as the leader in the 21st Century's race for energy innovation.

Efforts such as ARPA–E are crucial in our quest to catch up in this contest, which is also our best hope of providing future prosperity. Renewable energy technologies we can scarcely imagine today are destined to lead to a cascade of diverse, breakthrough products and vast numbers of high-quality jobs: for blue-collar builders, factory employees, and maintenance workers; and white-collar engineers, salespeople, and managers.

We Can't Lose Momentum

In a very short time, your determined leadership has brought us exciting progress. ARPA–E is serving an instrumental role in focusing researchers' attention on the right goals. But what happens after this year? It's distressing to imagine ARPA–E's funding may soon expire.

I'd like to remind you that when DARPA was created in 1958, it received a budget appropriation of $500 million, which is the equivalent of $3.5 billion in current dollar terms. This amounted to .67 percent of total Federal spending that year. Today, our Federal spending on all renewable energy represents less than .04 percent of current Federal outlays. In other words, DARPA's initial appropriation was more than 16 times the Federal budget share devoted to renewable energy research today. Certainly, today's jobs and environmental crises are every bit as threatening to our country's future as the impetus to DARPA's creation: the October 1957 Russian launch of the world's first earth-orbiting satellite, Sputnik.

I urge you to extend and expand ARPA–E's charter. It should be treated not as a short-term experiment within the DOE, but rather as a pillar of U.S. energy policy. Only then can we show the rest of the world, once again, how to lead an Industrial Revolution.

I appreciate the Committee's invitation to participate in today's hearing, and look forward to learning more about how we can work together to build a more secure and prosperous future.

BIOGRAPHY FOR JOHN DENNISTON

John Denniston is a Partner with Kleiner Perkins Caufield & Byers. At KPCB, John has worked with a wide variety of portfolio companies, with a primary emphasis on the Greentech industry. John was a member of the KPCB Partner team that many years ago conceptualized and launched KPCB's Greentech investment initiative. Since then, KPCB has been an active investor in the Greentech field, having invested in start-up companies across a wide variety of sectors. John is an active participant in KPCB's Greentech Innovation Network, a network of business, academic and policy leaders who meet regularly to identify, and then pursue, the most important green technology and public policy innovations.

He is actively involved in Greentech public policy issues, having testified before several Congressional committees. John serves on the Board of Advisors of the National Renewable Energy Labs. He is a frequent speaker at Greentech industry conferences.

Prior to joining KPCB, John was a Managing Director and Head of Technology Investment Banking, Western U.S. at Salomon Smith Barney. He also served on the Investment Committees for both Salomon's venture capital direct investment fund and CitiGroup's venture capital fund-of-funds. Before that, he was a Partner at the law firm Brobeck, Phleger & Harrison, where he was the Head of the firm's Venture Capital Practice Group, co-head of its Information Technology Practice Group, and served on the Investment Committee for its venture capital fund.

John has a B.A. and J.D. from the University of Michigan.

Chairman GORDON. Thank you, Mr. Denniston. And now, Dr. Pierce.

STATEMENTS OF DR. JOHN PIERCE, VICE PRESIDENT, DUPONT APPLIED SCIENCES IN BIOTECHNOLOGY

Dr. PIERCE. Good morning, Chairman Gordon, Ranking Member Hall, and Members of the Committee. My company, DuPont, is a 207-year-old innovation-driven company. We have 2,000 Ph.D.s, worldwide R&D operations, and active research programs with universities, national labs and commercial partners. Our former CEO and chairman worked with Dr. Vest on the National Academies report, *Rising Above the Gathering Storm*, where ARPA–E figured so prominently, so I thank you for this opportunity to share our perspectives on DOE's program.

We are active in a variety of energy efficiency solutions including bio-based materials, building efficiency and materials lightweighting. We are also active in low-carbon energy generation and storage technologies, including biofuels, solar, wind and advanced battery technology. Our seed company, Pioneer, expands the productivity of agriculture for food and fuel. With BP we are developing biobutanols and advanced biofuel that behaves like gasoline in existing autos and infrastructure. And Mr. Chairman, this Friday I am happy to go to Vonore, Tennessee, to celebrate the opening of our demonstration facility for cellulosic ethanol, which is a technology significantly enabled by DOE partnerships and Tennessee's visionary leadership and support. Our R&D portfolio is driven by market needs and expected returns for our shareholders. This serves near- and mid-term market needs fairly well, but public and private partnerships best serve the pursuit of riskier transformational technologies. ARPA–E serves a valuable role by focusing efforts on the critical energy sector as we have heard in the statements today and serves as a powerful springboard for promising pre-market concepts.

If supported additionally by government programs that help move new ideas from initial concepts through to commercial demonstration, ARPA–E can promote the U.S. leadership we need in clean energy technologies that create all the new manufacturing jobs. While ARPA–E is new, we can offer some observations based on our experience to date. They did an absolutely impressive job reviewing an enormous number of proposals and initial concepts. The breadth of the first grants appropriately reflected a wide-range of recipients including universities, start-ups, established companies. This inclusiveness provides access to the breadth of expertise that is necessary to seek emerging technology concepts as well as evolve them to commercial production and jobs.

Our ARPA–E selected project builds on our prior biofuels R&D investments. It enables our collaboration with Bio Architecture Lab, a start-up company in Washington State, with whom we will work on kelp—or seaweed—as an alternative feedstock for biobutanol.

Now, given our significant prior R&D investments in energy technologies, the use of a technology investment agreement for our project was critical for our participation. TIAs provide approaches

to patent rights and other terms that make it easier for commercial entities to partner with the government and integrate new projects into their existing R&D portfolio while being able to leverage the company's earlier work. A TIA can greatly reduce administrative complexity and facilitate effective collaboration between business and government, and we encourage a continued use of this instrument.

We have been very impressed by the level of engagement and responsiveness of the ARPA–E staff and the commitment and the enthusiasm they demonstrated.

Let me offer just a few thoughts as ARPA–E is built out. It is important to have a clear and transparent process for identifying funding areas, establishing priorities and systematically engaging stakeholders. And the anticipated fair upcoming is a great example of doing that. Regular funding cycles and rapidly evolving areas such as advanced transportation technologies would provide lead time to anticipate funding and assemble solid proposals. To fully realize the flexibility and timeliness required for their efforts, DOE should continue to give ARPA–E flexibility to try new and agile approaches. And of course, the effective execution of ARPA–E's mission requires highly qualified resources. I hope that we will see the appointment of more professionals in the near future as well as sustained Congressional funding.

In closing, let me thank you again for the opportunity to share our views with you. DOE has done a solid job of setting this new organization up, but it is clearly in its early days with opportunities to strengthen the organization and refine its mission as it grows. We appreciate the focus of the Committee on this important subject and look forward to working with you as ARPA–E progresses.

[The prepared statement of Dr. Pierce follows:]

PREPARED STATEMENT OF JOHN PIERCE

Good morning Chairman Gordon, Ranking Member Hall and Members of the Committee. My name is John Pierce, and I am the Vice President of Technology for DuPont's Advanced Biosciences efforts. I am pleased to be here today to share DuPont's perspectives on the Energy Department's Advanced Research Projects Agency. My personal perspective is informed by my work over the last ten years leading DuPont's R&D efforts in the area of industrial biotechnology that has yielded technologies like our Sorona biopolymer, for which DuPont received the President Green Chemistry Award, and the high performance biofuel biobutanol.

DuPont has long been an innovation company, from the development of polymer chemistry in the 1930s and 1940s, the development of synthetic refrigerants to replace hazardous materials in refrigeration, specialty fibers like bullet resistant Kevlar and fire resistant Nomex through our current biotechnology and nanotechnology work. We currently employ almost two thousand PhDs, and conduct major R&D operations in multiple countries, including the US, Europe, China, and India. We have active joint programs with many Universities and National Labs as well. More than 35% of our revenues in recent years derive from new products driven by a very structured and targeted global innovation program with spending of about $1.4 billion each year.

We have frequently collaborated with the US Government in our efforts over the years, whether through collaboration with the National Labs or competing for matching grant funding to advance technologies serving national interests. Our scientists also contribute through various external engagements with Universities, the National Academies, and Federal agencies. Our former CEO and Chairman Chad Holliday was a co-author of the seminal National Academies report *Rising above the Gathering Storm*, which originated the idea of an ARPA organization for energy.

The development of sustainable energy solutions is certainly an area in which DuPont is already focusing much of our innovation. We are working on energy saving technologies such as biomaterials, high efficiency lighting, transportation efficiency and advanced materials for building efficiency and energy storage. We are also active in low carbon energy generation and storage technologies that include advanced biofuels, solar, wind power and fuel cells, advanced batteries and environmentally friendly improvements to current energy supply technologies.

For example, we arc very engaged in advancing sustainable transportation solutions, including through biotechnology. We have developed technologies to produce advanced polymers from sugar that are going into automotive applications, and are deeply engaged in advancing biofuels on three separate fronts. Our seed company Pioneer is steadily expanding the productivity of grains used to produce first generation biofuels and sells varieties that specifically enhance biofuels production per acre. We have developed a technology to produce ethanol from cellulosic feedstocks such as switchgrass. I am happy to report, Mr. Chairman, that our biomaterials plant in Louden, TN is doing very well and on the 29th of this month we will hold a grand opening for our cellulosic ethanol pilot plant in Vonore, TN—a technology and facility that was significantly enabled by DOE partnerships. We have also worked with BP to develop the advanced biofuel biobutanol, which has high energy density and is compatible with existing autos and fueling infrastructure.

So let me turn my attention specifically to ARPA–E. Our perspective here is informed by our role as a market driven science company. Our R&D portfolio and the prioritization of funding is driven by customer or market needs, specific product opportunities, and the prospect of returns for our shareholders, rather than more "blue sky" kinds of exploration. That is our appropriate role in the innovation economy. However, as you might imagine, the scientists in DuPont generate some pretty interesting concepts that don't get into our innovation pipeline because we need to prudently manage the risk of investing in very early stage technologies with uncertain market opportunities. This pragmatic approach to R&D funding prioritization is an economic necessity for the private sector. While it serves near to mid term market needs quite well, it does not provide for the development of transformational technology options with broad societal relevance. This is a gap that government funding can most effectively fill. ARPA–E serves a valuable role in focusing that government effort on the critical area of energy.

An entity like ARPA–E can act as a powerful launching pad for early pre-market concepts to be evaluated and pursued. Cost sharing with ARPA–E can sufficiently reduce the risk to enable companies like DuPont to commit R&D resources to more transformational technology efforts, in collaboration with the government and other partners. This capability complements and enhances the incredibly valuable and robust US academic research enterprise that already receives substantial funding through a variety of government programs, and provides a necessary bridge across the "valley of death" between scientific discovery and commercial practice.

Such efforts also need to be part of a web of programs that help new ideas get from initial concept demonstration through to commercial demonstration if the US is going to retain and expand its leadership role in critical technologies—and provide the high paying manufacturing jobs such leadership provides. There is a growing concern that the US is losing its manufacturing edge, which is a critical part of our innovation engine. We in the US are at the leading edge of biopharma, biomedical devices, and will soon lead in bioprocessing for small molecules. We have created that edge and maintained it thus far by keeping the manufacturing here. Government investment in the early phases of research—as in ARPA–E—as well as the development phase for building pilot plants and demonstration units for those areas of technology that are truly transformational will help us hold our edge.

It is particularly important that the US find ways to expand and accelerate research, development and deployment of low carbon solutions in energy production and use. The cost, security implications and environmental ramifications of our current energy trajectory is clearly unsustainable, and the response to this challenge will be a significant area of economic activity and global competition in the coming years in which the US must not fall behind.

While it is premature to draw detailed conclusions regarding the functioning of ARPA–E given its relative newness, we can offer some observations based on our experience in responding to their first solicitations and being selected for a matching grant.

First, for the level of staffing they currently have we feel they did an impressive job of sorting through an incredible number of initial concepts submitted to them. Second, the breadth of topics selected for the first grants is a positive sign, suggesting an appropriate range of thinking and perspective. Third, they also selected a wide range of recipients, including Universities, start ups and established compa-

nies such as ours. This inclusiveness is important as it provides access to a wide range of expertise, including knowledge communities that the commercial world looks to for its technology pipeline, but also includes entities whose engagement is necessary to make the transition from technology concept to robust manufacturing methods to commercial production and stable jobs.

For example, our project that was selected for ARPA–E funding leverages our significant prior biofuels R&D investments that I described earlier. It allows us to explore a new and promising area that, while attractive, we would not have funded on our own until well in the future as we allocate resources to nearer term technology applications.

This funding will allow us to expand the potential of our biobutanol technology to new and promising feedstocks. Under the grant DuPont is partnering with a start-up company, Bio Architecture Lab of Washington State, that has close ties with the University of Washington. We are working to develop approaches to employing kelp, that is—seaweed, as an alternate feedstock for the production of biobutanol. This also illustrates how ARPA can help to facilitate collaborations amongst different kinds of players in the innovation pipeline, in this case an established firm and a technology startup.

Given DuPont's significant pre-existing investment in technologies for sustainable energy, ARPA's ability to provide a Technology Investment Agreement (TIA) as the basis for our project made it easier for DuPont to participate in the first solicitation. TIAs provide approaches to patent rights and other government terms that make it easier for commercial entities to partner with the Government and integrate new projects into their existing R&D portfolio than is allowed by the more restrictive terms of alternative funding models. Unlike contract research entities, commercial firms do research with an eye to products and services, continually seek synergies across their research programs, and need the ability to see their way to future opportunities in a way that allows the seamless integration of self-funded and government funded capabilities. A TIA can greatly reduce administrative complexity and thereby facilitate effective collaboration between business and government. We would encourage the continued use of this instrument in solicitations in the future.

Finally, DuPont has been very impressed by the level of engagement and responsiveness by ARPA–E staff, and the commitment and enthusiasm that they have demonstrated. When agency staff responds to a question within two hours it is pleasant. When that question was submitted at 8:00 p.m. and responded to by 10:00 it is a pleasant surprise.

Going forward we would like to suggest a few considerations as ARPA–E is built out. We believe it is important for the program to have clear and transparent processes for identifying the grand challenges that merit funding; establishing priorities, systematically engaging the appropriate communities of knowledge at an early stage, and announcing focused funding opportunities in areas where sufficient scientific evidence exists to justify such investments. Establishing external advisory panels can help ensure that a breadth of perspectives is brought to bear in developing the ARPA agenda. It may also be helpful for ARPA–E to have regular funding cycles in critical areas where the science is evolving rapidly—for example, every three years ARPA could invest in advanced transportation energy technologies. This would allow researchers in this sector sufficient lead time to anticipate funding and assemble ideas and collaborations to develop the most competitive proposals. Clearly, the effective execution of ARPA–E's mission requires the rapid addition of qualified program resources, and I hope that we will see the appointment of many more professionals in the near future, as well as sustained Congressional funding.

In closing, thank you for the opportunity to share our views with you today. We think DOE has done a solid job of setting this new organization up, but it is clearly in it early days, with opportunities to strengthen the organization and refine its mission as it grows. We appreciate the focus this Committee has brought to this important subject, and look forward to working with you as ARPA progresses.

BIOGRAPHY FOR JOHN PIERCE

John Pierce is vice president for DuPont Applied BioSciences—Technology, with responsibility for DuPont's biotechnology research and development efforts in the production of fuels, chemicals, and materials.

Dr. Pierce began his career at DuPont in 1982 as a research scientist in Central Research & Development (CR&D). He moved to Agricultural Products in 1988 and held research management positions in agricultural biotechnology and subsequently in crop protection chemical discovery. In 1994 he became director of Chemical and Biological Sciences in CR&D, where DuPont's current focus on industrial biotechnology began to take shape.

From 1996–1998, Dr. Pierce was planning manager for Agricultural Products' Europe, Middle East, and Africa in Paris, France. Upon returning to Wilmington, he worked to integrate the agricultural biotechnology research efforts of DuPont and its subsidiary Pioneer Hi-Bred International. He first served as director of Genetic Resources and subsequently as director of Strategic Resources and Planning for DuPont Crop Genetics Research. In 2001, Dr. Pierce returned to CR&D as director of Biochemical Sciences and Engineering and was named to his current position in June 2006.

Dr. Pierce has been intimately involved in the evolution of DuPont's positions with respect to commercialization and acceptance of biotechnology products. He was a founding board member of the Society of Biological Engineering and currently serves on the Management Board of the BioEnergy Science Center at Oak Ridge and on the Scientific Advisory Board of the Great Lakes Bioenergy Research Center—two DOE sponsored consortia developing biofuels from renewable resources.

Prior to joining DuPont, Dr. Pierce held postdoctoral positions at Cornell University and the University of Wisconsin. He holds a bachelor of science degree in biochemistry from Penn State and a PhD degree in biochemistry from Michigan State University.

DISCUSSION

Chairman GORDON. Thank you, Dr. Pierce. At this time, we begin our first round of questions and the Chair recognizes himself for five minutes.

KEEPING JOBS AND INNOVATION IN THE U.S.

Dr. Majumdar, in your testimony you mentioned that one of your worries was making sure that we kept this technology here in this country and turned it into a product and to jobs. And so I would like to ask Mr. Denniston and Dr. Pierce, what does he need to do

so that the venture capital community will come in and major other companies will come in and take these technologies? At what level does he have to raise these?

Mr. DENNISTON. Yes, I think it is a wonderful question and exactly the right one to discuss. So as I mentioned in my testimony, the investment community in the United States doesn't have a sufficient number of at-bats of high-quality research opportunities in energy. It is because the area has historically been grossly underfunded in my opinion and I think in the opinion of most researchers.

I and my partners have gone around to the leading research institutions in this country, and it would shock you, notwithstanding the world-class talent that we have at those institutions, how few projects there are in the energy field—breakthrough, revolutionary projects—and it is not because the interest isn't there, it is because there isn't funding.

So the numbers, if you are interested, are that annually, setting aside ARPA–E, going back a decade or so, DOE has had roughly a billion and a little bit more per year to invest in renewable energy research throughout the United States. That is for an industry that in the United States is roughly $1.8 trillion, a tiny fraction of the industry's size, by comparison. We are also working to cure human disease, and this Congress has for decades set that as a high priority to the extent that today NIH has an annual budget of $30 billion. That is terrific. Maybe it should be higher. It certainly shouldn't be less. The interesting thing to bear in mind is the healthcare industry is almost the same size as our energy and transportation industries, 15 percent of GDP each, and yet we have a 30-to-1 funding differential between the two. On the one hand, curing human disease, on the second, putting this country in a position poised to win and lead the second industrial revolution.

So what ARPA–E and its leaders can do is keep on doing. I think they did a fabulous job in their first round of funding awards, and I think you, the Committee, the Congress, the Administration, can help them by, as I said before, extending and expanding ARPA–E's charter, making this a pillar of U.S. energy policy.

Chairman GORDON. So you want a bigger menu? And what about you, Dr. Pierce? What is going to excite DuPont to make an investment here?

Dr. PIERCE. I agree with the assessment that the energy sector has been not looked after as much in basic research over the past as some others. The intention is changing with a lot of people with national security, greenhouse gases, climate change and the like. Same thing with our own company. These types of funds are very important. My company spends $1.4 billion a year on R&D. So that is small by government terms, I understand, but we use it all up. And my scientists have got way more ideas than $1.4 billion, and we have to focus those ideas more on the near-term. So having the kind of investment that allows us to partner with start-up companies, to partner with universities for some of the riskier ideas, allows us then to flange up some of our more developmental capabilities and then take the technology from concept all the way through. So one has to have the concepts laying around to start with, one has to give them a little bit of funding to get them going, but one

also has to flange those up to scalable processes. And that is what excites us at my company.

Chairman GORDON. This the 50th anniversary of the laser, so it is a good example of how that research is paying dividends.

SCALING UP FLEDGLING TECHNOLOGIES

OK. So, Dr. Majumdar, it seems to me that we have to do more than just put, you know, throw money at it. I think that you have also got to somehow again raise the level, help these new ventures to be able to determine they can be scalable. What else are you doing to get them ready for the venture capital field or for the big corporations?

Dr. MAJUMDAR. I think it is very important for ARPA–E as an organization to pay attention as to who we recruit because I think we really need to have the best and the brightest to come on board for a short time and help. So what we are doing right now, as I mentioned in my oral statement, is that we are recruiting some of the best and the brightest to come on board, and what they are doing is to provide technical support and scrutiny for these teams out there, like Tony Atti's team out there. And the idea is that if there is a technological barrier, these program directors go out there and say why don't you talk to this person? Can you read that paper out there? And that is the kind of thing that is absolutely helpful for small businesses or teams in academia to actually make progress fast. And if they fail, it is important to learn quickly where they are failing and learn from that and make progress.

Chairman GORDON. It is almost like an MEP [manufacturing extension partnership] program that you are providing them with in-house?

Dr. MAJUMDAR. That is right. So that is the first aspect. The second aspect is about the adoption of technology that Mr. Denniston talked about. I think that is one of the fundamental differences between DARPA and ARPA–E. In DARPA there is a customer, and we know where this technology is going to go. And the Secretary of Defense can say thou shalt buy the technology. That is not quite true in the energy sector. So who adopts the technology and what is the commercialization pipeline is very critical. And so what we have done is to put an adoption team, a commercialization team, to look at what is the landscape beyond what happens in the labs right now. And then, of course, we have an operations team which is trying to expedite the process. And as I said, we have been able to do things in three months which have really not been done before. So that is the other thing. Then we are putting together a team looking at the outreach side, to be able to tell the public what we do, and the value of what we do.

So when someone gets dollars from ARPA–E, they get the whole team to work for them, and we are trying to look at the other side where it would be awardees, and trying to find out best practices of their team so that these teams can work together. So that is what we are trying to do right now.

Chairman GORDON. Thank you, sir. And now I recognize my skeptical friend from Texas and hope he is feeling better.

PRIORITIZING ARPA–E'S GOALS

Mr. HALL. Mr. Chairman, thank you. I do feel better, and I continue to be amazed at the quality and the caliber of the panels that you have attracted here. President of MIT? I couldn't have got in MIT, and I sure couldn't ever got out of it.

This is a subject that I think this Chairman is going to be remembered for always, and it has been a pleasure. Dr. Majumdar, I hope I said that right, I note that you were probably confirmed earlier than anybody in the history. I see here you were appointed in September by President Obama, and you were confirmed in October. If that was in the same year, I think it took you about 15 days to get confirmed. So your reputation was here ahead of time. Thank you for the service you are going to give us.

I will ask you my first question. I think the statutory charge for ARPA–E states that its goals should include pursuing energy technologies that, A, reduce our dependence on foreign energy, and that is something every candidate says they are going to do, B, reduce greenhouse gas emissions. Recognizing that there is some overlap between these goals, how do you prioritize them? Would you like to start with that?

Dr. MAJUMDAR. Sure. I think that is a great question, Congressman. Let me answer that question with an example. In the second round of the funding opportunity announcement, one of the topics that we focused on was something called electrofuels. That was the program that we created. That is a completely new concept. What it does is killing four birds with one stone. Let me explain that. Electricity, when you move electricity from wind or solar, it is hard to store, and with the intermittency, the storage is a problem. Hydrogen is hard to store. The best way to store hydrogen is hydrocarbons, which is gasoline. Carbon dioxide is a greenhouse gas. So the program is putting targets and challenges for the technical community, how to combine electricity, hydrogen and carbon dioxide to create gasoline, which we import 60 percent. And so this is a program where it is killing, as I said, four birds with one stone, carbon dioxide, hydrogen, electricity, and create gasoline.

And so that is something that is an example of how we can solve two problems or three problems with one approach.

Mr. HALL. I thank you for that. Were that if all things are equal, how you would weigh the potential of one project to improve energy security versus this potential to reduce greenhouse gas emissions?

Any of you want to comment on that?

Dr. PIERCE. I might comment. I think that the goals of getting renewable transportation fuels couples just straight ahead and overlaps dramatically with the security situation. We have lots of advantages in the United States with agriculture, we do have knowledge of how to make transportation fuels, and since today, basically all of the transportation fuels other than the stuff we grow at home, come from elsewhere, then moving along in the area of renewable transportation fuels goes to the very heart of the national security as well as greenhouse gas emissions issues.

Mr. HALL. I thank you and I will also ask in pursuing ARPA–E's statutory goal to reduce dependence on foreign energy that is all of our thrust here, how much focus have you or will you give

to supply-side technologies that increase domestic energy development and production including, and I am from an oil and gas state, for example, oil and natural gas as opposed to those that reduce demand through increased efficiency?

Dr. MAJUMDAR. Well, let me give you an answer with an example again. For example——

Mr. HALL. I like those four times completion.

Dr. MAJUMDAR. Well, we do have imports. We are importing 60 percent of our oil from countries that may not always like us. On the other hand, we have the largest reserves of coal, but the problem with coal is that the carbon dioxide emissions have greenhouse impact, climate change impact. So now the other two funding opportunity announcements that we have made in the second round, one is in advanced batteries because if you can store the electricity that is created from coal, then you could use that for transportation and reduce our need for imports of oil. So that is one. So at the same time, the carbon dioxide that is emitted could also be harmful. So the second program that we announced is called IMPACCT. It is Innovative Materials and Processes for Carbon Capture Technology. So if you can now look at collectively the carbon capture side and the battery side, we could then collectively address the problem of energy security as well as greenhouse gas emissions.

Mr. HALL. I yield back any time I have, Mr. Chairman. Thank you, and thank you for those good answers.

Chairman GORDON. I think Mr. Hall wanted to know how you can pump more oil and gas there in Texas. I think there is still going to be plenty of room for that.

Dr. Baird is recognized for five minutes.

Mr. BAIRD. Thank you, Mr. Chairman, and thanks to our distinguished panel.

RETAINING INTELLECTUAL PROPERTY AND MANUFACTURING IN THE U.S.

We have all hit on an issue that I think is absolutely critical, and there was a very troubling article in Harvard Business Review last year which addressed much what Mr. Denniston and Dr. Vest had talked about and that is that we often develop the core technologies only to see them exported. And Mr. Denniston, your comments about battery technology, my understanding from that and other readings in science and elsewhere is that it was not just a lack of funds. It was, we developed the technology and folks said, OK, you know, we can outsource the manufacturing of this, the fabrication of it. But once you outsource the fabrication, your engineers lose the hands-on experience and the interaction with it. And that then leads—we outsource battery manufacturing for cell phones, and then of course now we want to build big batteries for cars. We don't have the know-how to do it. So my question really is, and Dr. Majumdar, I am really impressed with this idea that you have got a complex organization that mentions how specifically to help people get to market. That article and others have given specific suggestions about what fundamentally has to change in our government structure and our funding structure and our regulatory structure and our manufacturing processes. How are we going to address that side? Because if the wonderful wizards who come up

with these things do so only to see it exported in its fabrication or further development, we haven't solved anything. We have just helped other countries beat us again. Give us some insights into this.

Dr. MAJUMDAR. So let me just say that is one of the things I mentioned in my oral statement is that this is a concern of mine, that we innovate and then someone else does the scale-up. I think as I mentioned that part of the reason why we are having this Energy and Innovation Summit is to figure out what are the specific recommendations that you can have both on the policy side, on the financial side, and what tools and instruments that we can create to keep the innovations out here for scale-up and then export the high-value items.

As I mentioned, one possible route, and I don't know exactly how to work this, but as I said, the government is a big purchaser of energy. And if there could be some provision that if a technology and its manufacturing in the United States meets certain performance standards and cost metrics, not to give them any break in cost, and if that could be pulled in, that creates a demand pull, which I think could really help getting small businesses and others get a foothold. And once they get a foothold, then let the business take over and then they can export the goods. I think that is one——

Mr. BAIRD. A very similar issue gets raised in the area of pharmaceuticals in terms of developing orphan drugs and where is the market going to be. And you are exactly right. In DOD, they have got a market. You build it, we may buy it. So I think we ought to look at that, Mr. Chairman, and we ought to look at that with other aspects. The Transportation and Infrastructure Committee has looked at it, for example, and actually in stimulus, as you know, there were some measures to put renewables on more Federal buildings.

Mr. Denniston?

Mr. DENNISTON. Yes, Representative Baird, I think it is a wonderful question. I will say this, that my firm, Kleiner Perkins, has invested in nearly 50 renewable energy companies, green tech companies, and I will tell you that many, many of them are aiming to ramp up their initial production in the United States of America. And it makes all the sense in the world to do that because from an effectiveness and an efficiency perspective, it makes a lot of sense to have manufacturing near research and development.

And so I think you will see manufacturing, blue collar jobs, happening in the United States as we ramp up the green tech sector. So the question is from a policy perspective, what can be done? Take your battery example. You are absolutely right. A lot of those innovations occurred in the United States. The U.S. market share for advanced batteries today is one percent. It is shameful. It is absolutely shameful. But imagine if DOE had had funding over the past couple of decades for advanced battery technologies, and just imagine that a breakthrough had occurred here in the United States that has a five- or ten-fold performance advantage over the incumbent batteries.

Mr. BAIRD. But my fear is, and I respect that, but my fear though is we come up with the technology, and it exports for the fabrication side.

Mr. DENNISTON. And my answer, Representative, is we have got to take it one step at a time. And what I am telling you as from a business perspective, it makes all the sense in the world to have initial production near research and development. And if we invent the technology here, there is a very good chance that the initial production will be in the United States. Then we can talk about the next step. How do we keep it here? We need it here from the get-go. We have this new industrial revolution where there will be all sorts of breakthrough technologies invented. They are happening now overseas. We don't have enough funding here. That is the gap that ARPA–E needs to fill.

Mr. BAIRD. Mr. Wu wanted to offer a comment.

Mr. WU. Yes, and Mr. Baird may have already commented on this, but when I took a test ride in an electric car right here in front of this office building, the electric car people said, you know, this technology was developed here but we are going to build the batteries in China, and that is very, very concerning to me. I yield back.

Mr. BAIRD. Thank you, Mr. Chairman.

Chairman GORDON. Thank you, Dr. Baird. I would quickly add that part of the equation is the other piece of COMPETES and that is we have to have a workforce here. These aren't minimum-wage jobs that are going to be created with these breakthroughs. They are going to be higher level. We have to have a technical-level workforce, and we will do that with other parts of the COMPETES bill.

Now as usual, my friend from California is always an early arrival, and so my comrade Rohrabacher is recognized for five minutes.

INTELLECTUAL PROPERTY AND COMMERCIALIZATION

Mr. ROHRABACHER. Thank you, Mr. Chairman. Let me just identify myself with the points made by Mr. Baird which I think are significant, and I am going to be very generous and say that I don't believe the answers he received are adequate to deal with the problem that he outlined.

Perhaps the solution, and let me ease into this, is that we make sure that anyone who manufactures an American-developed product has to pay the royalties that are necessary for the intellectual property that they are using because what we are creating is intellectual property here. Is there any type of requirement with this money that we are providing for research and development will go—who owns the intellectual property at the end and is there a requirement that the intellectual property should be used and could we make that restriction that it could be only used in manufacturing or certain fees would have to be paid to the United States government for providing this benefit?

Dr. MAJUMDAR. Sir, one of the requirements that we have since this is Recovery Act money that we are awarding is that 90 percent of the manufacturing is done within the United States, the 90 per-

cent of the work is done within the United States in the ARPA–E awards that we are making.

Mr. ROHRABACHER. The work that is done in the development but not afterwards?

Dr. MAJUMDAR. Right.

Mr. ROHRABACHER. After someone owns the—who owns the intellectual property in this?

Dr. MAJUMDAR. The company owns the intellectual property. The Department of Energy has rights to that. If they want to take it outside, they have to come to the DOE for waivers. And so the DOE can then—Department of Energy has marching rights if they are not doing anything with the intellectual property as well.

Mr. ROHRABACHER. OK, but the Department of Energy owns the intellectual property? You get a grant from—DuPont studying seaweed. Now, I am going to have to tell you when I ask you this in a moment, for the taxpayers to be subsidizing a huge, multi-billion dollar corporation in order to study seaweed does not sound like a good decision for me. But let us say that it comes through, you know. Let us say that DuPont's research, this $9 million we have given this multi-billion dollar company, actually does produce a new idea about using seaweed for energy. Who owns that? Does DuPont own that or do we have, as taxpayers, have some share in the ownership?

Dr. MAJUMDAR. I think that is a very important question. I think what the Department of Energy or the government can do is to help the technology advancement and then help enable them to, you know, succeed in business. So in that sense, the intellectual property that is owned by the company, but the Department of Energy has rights that if they want to take it outside the United States, they have to come for a waiver. And so we want to make sure that the manufacturing——

Mr. ROHRABACHER. So anybody who manufactures utilizes the technology that DuPont has, DuPont is going to continue making all the profit but the Department of Energy has a waiver on whether they can sell this, let the Chinese manufacture this?

Dr. MAJUMDAR. No, they have to come to the Department of Energy for a waiver, and then we have to consider that for, you know—the point is to have the benefits——

Mr. ROHRABACHER. I am not talking about the money being spent on research. I am not talking about outsourcing research. I am talking about the same point Mr. Baird brought up is that we are spending all of our money on research, and we end up doing nothing but serving as an engine for China and other countries to out-compete us with what we have developed here.

Dr. MAJUMDAR. Which is the concern that I also mentioned earlier, that I think it is very important to make sure that the scale-up of these innovations really happens in the United States.

Mr. ROHRABACHER. OK. Now, let us talk a little bit about DuPont. Why is it that we, taxpayers and everybody is having to pay for this, is subsidizing this research for a multi-billion corporation into seaweed?

Dr. PIERCE. Yes, sir. Let me make one comment or clarification about your questions before, about the commercialization.

Mr. ROHRABACHER. All right.

Dr. PIERCE. It is absolutely right that the requirement is that this be substantially commercialized in the United States, and one must go to the DOE for a waiver if one wants, if DuPont decides that China is a good place to commercialize this. We have to go ask the DOE, and the DOE will point to the statute and discuss, have you substantially done something in the United States, and if not, why not?

Mr. ROHRABACHER. OK. So in other words, this new technology that you are developing, seaweed or whatever, once you have accepted this grant, your company cannot sign a contract that permits a Chinese company to build the seaweed manufacturing facility over there unless our government approves of that? Not the development, the actual utilization——

Dr. PIERCE. You are talking commercialization right now, right?

Mr. ROHRABACHER. So does DuPont, is there some sort of ownership rights that we have to the intellectual property, the government maintains?

Dr. PIERCE. My understanding is, and if there are some lawyers in the room that would be helpful, but DuPont owns the intellectual property. We have rights to use it in a certain way. We are required to commercialize substantially in the United States. That doesn't say you can't do anything anywhere else, but you have to do it substantially in the United States. And if some argument arises as to this is the reason one cannot do it substantially, and I don't know what it would be, but let us imagine, right? Then one goes to the DOE with that argument, and the DOE——

Mr. ROHRABACHER. OK.

Dr. PIERCE. —passes on that argument.

Mr. ROHRABACHER. So we do have some leverage to handle the problem that Mr. Baird brought up?

JUSTIFYING SUPPORT FOR R&D AT LARGE CORPORATIONS

Dr. PIERCE. Right. And then in terms of big old DuPont getting $9 million, let me say that from a straight government perspective, DuPont——

Mr. ROHRABACHER. OK.

Dr. PIERCE. DuPont has invested many multiples of $9 million of our shareholders' money to enable a bunch of technology which is being leveraged by the government's investment of $9 million. So if we were looking at this from a straight commercial transaction point of view, a little bit of governmental money is leveraging a whole lot of private sector money.

Mr. ROHRABACHER. Is there a time limit on this restriction? Just one last question on this. Is there a time limit on this control that we have that says what the research money will not be used for manufacturing overseas, at least substantially it would have to be here? Is there a time limit on that restriction?

Dr. MAJUMDAR. There is no time limit, sir.

Mr. ROHRABACHER. OK. Thank you.

Chairman GORDON. Feeling better?

Mr. ROHRABACHER. Thank you, Mr. Chair. Well, am I ever?

Chairman GORDON. Ms. Fudge is recognized.

U.S. STEM Education and Federal Renewable Electricity Standards

Ms. Fudge. Thank you, Mr. Chairman, and thank all of you for being here today. I do want to just raise the point that as we talk about competition with China, if you look at college graduates in China, more than 50 percent of them receive diplomas in engineering or natural sciences, where in this country it is about 15 percent. So I certainly hope that as you talk about how we turn some of this around, that there is some serious consideration given to how we change that in a very, very short timeframe. I mean, you know, we are talking about STEM and a lot of things but right now we have the same problem with our NASA people and all across the board. So there has to be something done to get more people into either STEM education, but I think that is a long-term process. I think we have to find a way to get more people into engineering and natural sciences.

But my question for the panel is would the implementation of a Federal renewable electricity standard have any impact on the investor community? Do you think that that is something that would help? Anyone.

Mr. Denniston. I am happy to answer that. The answer simply is absolutely, yes. I think it is a fabulous idea because it would give certainty of a market. And so 29 states have done that, but the policies between the 29 states that have an RPS, RES, use the acronym that you wish, are not consistent. And so I think having a consistent RES at the national level would send a wonderful and strong signal to America's entrepreneurs, innovators and inventors. And I am very, very positive on that idea.

Ms. Fudge. Thank you.

Dr. Atti. Ms. Fudge, if I could add to that quick comment on your previous statement in terms of education, the one thing that absolutely keeps me awake every night as an entrepreneur is how to staff our company with the best and brightest, and it is not easy. I think the importance of ARPA–E at this stage in bringing in the professional investment community that Mr. Denniston represents is now I can leverage not only my network of top scientists, but also their network and ARPA–E's as well, which is so critical because now time is my enemy, and bringing those people on board is very important. So the more dialogue between the investment and technical communities that we can encourage, the absolute better.

In terms of a standard, while our company is still very early in technology development, I have been shocked at the number of potential customers that have reached out to our small start-up company. Many, particularly on the industrial waste heat recovery side, heavy users of electricity, heavy industries here in the United States, first look at waste heat as a real issue of lost efficiency and mitigating their electricity costs. Many feel that there is some standard coming down the pike, either in terms of CO_2 emissions or renewable mandate, but they don't know what it is. So they are interested in this waste heat recovery both for practical purposes in terms of mitigating a pressing need right now, but also looking

at a standard that may or may not evolve at the state, local or Federal level.

So my ability to position our company and our products in the marketplace can only be helped if there is some streamlining of those standards.

Ms. FUDGE. Thank you.

Dr. VEST. If I might comment very briefly on both of these lines of question, first of all, across Asia, 20 percent of the college graduates are engineers. Across Europe, about 13 percent of the college graduates are engineers. In the United States, that number is 4.5 percent. This is frightening because it is in fact the engineering community that has to translate these new ideas and these research results into real products and services.

Secondly, if I might, I have great empathy for concern that our answers are not sufficiently specific on this issue of globalized manufacturing, et cetera. But I must return to basics. This is all about igniting people and innovation. Part of the solution to this educational problem is to set an exciting vision and agenda for science and engineering, and energy has got to be at the core of that. The fact of the matter is, we are not going to stop globalization. We know that. But our only chance is to be the ones leading in the newest technologies and grab them and develop them as fast as we can, as much of it done here as possible. It is eventually going to spread around the world, but if we are not generating the new stuff, then we are in deep trouble.

Dr. MAJUMDAR. Can I just add a quick answer to that?

Ms. FUDGE. Yes, thank you.

Dr. MAJUMDAR. I think it is a wonderful question. I have, for my adult career, have been in the university, in academia, and one of the things that I am seeing right now is this grass roots movement, a sea change of interest among the students, whether it is science or engineering or business or public policy, where they have all come together and they are really energized about energy. And this is new. This was not there a few years ago. And I think we need to grab that and run with it and give them a little bit of power, empower them. And the ARPA–E Fellows Program is really to do that.

Chairman GORDON. Thank you. And Mr. Smith is recognized for five minutes.

LEVERAGING PUBLIC MONEY FOR PRIVATE INVESTMENT

Mr. SMITH. Thank you, Mr. Chairman, and witnesses for your giving of your time today.

I know that we have touched a little bit on my concern, but certainly the challenges that we are facing, kind of like being asked an either/or question and responding with yes, and you know, what should come first, the private venture capital or what is appropriate, private venture capital or these government dollars and then who owns the technology from there.

So, Dr. Majumdar, if you wouldn't mind telling us or maybe giving us a good example of where perhaps private dollars preceded or followed public dollars and how maybe that was leveraged, is it appropriate? What might you have to say?

Dr. MAJUMDAR. Well, I think this is a very important question that we are discussing sort of almost on a daily basis. I think an example in terms of private dollars—you said private dollars preceding the public dollars? Is that what you meant? Well, I can't see if I think in the cases that we have seen it is public dollars really preceding. I mean, what we are trying to do is invest in many different approaches to the same technology—we don't know which one is going to actually win. And let the business take over and see which ones actually win.

I am going back to an example of the days of the transistor. If you look at the microprocessors today, there is only one design of the transistor which has worked. But if you go back, there have been 10 or 20 different designs of the transistor. Not all of them worked out. And so what we are trying to do is to look at the various approaches, and one of them or a few of them could be business-ready and let the private sector take over. But we are investing in sort of the upstream part of it.

Mr. SMITH. Thank you. Dr. Pierce?

Dr. PIERCE. Yes. Let me give an example that's close to home and evolving right now. I had mentioned that we are opening this cellulosic ethanol facility in Tennessee on Friday, and that came out of the joint work that we and our partner——

Chairman GORDON. Not in my district, just so everybody knows.

Dr. PIERCE. It is right next to his district, though, I believe. And this was enabled by DOE funding, both to ourselves and the Genencor enzyme company. Now, one of the reasons we were competitive for this is that DuPont independently back in the early '90s started learning how to do this modern biology. We set up a fancy fermentation facility to make a molecule called propanediol, also in Tennessee it turns out. And we learned how to do all this new technology with DuPont shareholder money, and once we had that kind of technology, kind of like some of the panelists were saying, we had a capability to do something so that when we approached DOE, DOE could say, oh, you are pretty good at that. Here, have some more money to do this riskier cellulosic ethanol stuff.

So this is all a continuum of back and forth government-private things, and I think you can find numerous examples of all permutations.

Mr. SMITH. And what would happen if you did not have access to public dollars?

Dr. PIERCE. Well, I can tell you. We were feeling really frisky after we came up with the technology for this propanediol, and this is a molecule DuPont had wanted to make since the 1950s but we could never make it cheaply enough chemically. And then the biologists did it, so we were feeling good. But we sat down. I remember sitting in Wilmington saying, boy, we think—this was in 2001—we think cellulosic ethanol is a big thing, and that is before it got all crazy, you know, in 2005 where everyone was talking about cellulosic ethanol. But we looked at it and saw the size of the challenge and said there is no possible way we can approach that in a serious way, despite feeling strong and being a big company, without government support, and we started getting on the train and coming down here and talking to you all about it.

Mr. SMITH. OK. Thank you. And I just want to use briefly the remainder of my time to touch on and perhaps if any of you wish to respond that, you know, I believe it is this Committee and this Congress' responsibilities to encourage innovation, and I am very concerned that some other policies, and I won't elaborate on those, are an attempt to regulate something into existence. I know that that is a far different story than regulating something out of existence. And I hope that we can be innovative about things and not try to get too clever into attempting to regulate something into existence. If anyone would wish to——

Mr. DENNISTON. I would appreciate the opportunity to respond to that. Different Members of Congress can have their own objectives in mind. I don't look at ARPA–E as trying to enable something into existence. This market is happening, and as I pointed out in my testimony, it is happening overseas. We are behind in this race, and we are behind in this race in significant part because of the dangerously deficient funding at the Federal level for technology breakthroughs. These are massive markets. I will give you an example. The solar market today is in excess of $40 billion globally. That has already surpassed the size of the internet search market. These are massive industries, large and growing and we are not in the game the way that we need to be, the way that we historically have been. And with respect to the issue that has come up from a number of the questions is how can we keep the jobs, particularly manufacturing in the United States, and I would respectfully suggest that we don't—all of us share the concern about jobs in the United States, blue collar, white collar, not having manufacturing bleed overseas, no question about that. I don't believe that the answer and the solution to that is to cut research and development. That doesn't solve the problem. If Congress is interested in solving the jobs bleed problem, I would highly recommend that this Committee and others have a hearing on that subject. The topic of this hearing is Research and Development for Advanced Energy Technologies, and as I said before, in our portfolio, I can tell you that many of those companies will manufacture in the United States for the reasons that I suggested. Others need to. Fuels, for example. They weigh a lot. It doesn't make sense economically to transport them from overseas. And even if some of those breakthrough technologies in part in the future get manufactured overseas, there will be research and development jobs here, and it gives us a chance. So I am very concerned about manufacturing, too. I think we are conflating two issues, and again, I don't think the solution to the manufacturing jobs issue is to cut or limit research and development here or to put strings on funding so that companies can't manufacture overseas. I don't think protectionism is the answer to the problem. I think it is innovation.

Chairman GORDON. Thank you, Mr. Smith.

Mr. SMITH. Thank you.

Chairman GORDON. And Ms. Dahlkemper is recognized.

HELPING SMALL BUSINESSES ACHIEVE MARKET BREAKTHROUGHS

Ms. DAHLKEMPER. Thank you, Mr. Chairman. I want to thank the panel for joining us today.

Dr. Atti, I want to ask you a question. I am from Erie, Pennsylvania, so you certainly know the kind of district that I have.

Dr. ATTI. Yes.

Ms. DAHLKEMPER. It was always a manufacturing base. We have lost a lot of our manufacturing. I see this research as being the innovation that we need to help those manufacturers throughout that region to come forward. I have some people who have great ideas. What I want to ask you about, your company, a small firm, what do you see as a biggest barriers for small companies to reach the market with breakthroughs? What extra tools and resources do we need to provide through ARPA–E to enhance that transfer of technology from the program to our business community so that areas of mine can see the positive economic effects going forward? And after you answer, anyone else who wants to comment on that, please do.

Dr. ATTI. That is a heavy question. There are a lot of parts to building a start-up company. Geography is just one very important part. It goes to the heart of the question of how do you appropriately transfer technology out of a university setting? So if you think technology agnostic for the moment, whether it is energy or IT or biotech, you want to try and build some kind of a cluster that involves your universities where this fundamental research is done, partnership with the industries that are in the area or the infrastructure that exists in terms of our neck of the woods. There is a lot of infrastructure and capacity that is under-utilized. There is a very strong regulatory element to it as well in terms of our company, when we ultimately decide where module fabrication goes. We will take advantage of an existing semiconductor infrastructure here in the United States. There will be infrastructure upgrades and equipment capex [capital expenditures] purchases that we will have to make that my investors are not always willing to pay for through equity where credit can be used to help accelerate those purchases. And then lastly, bringing the people together in critical mass in a particular area as opposed to having to search all around the country to bring them together. There is no one fell swoop answer to this particular issue.

In our instance, I live in Raleigh-Durham, North Carolina. There is a very strong entrepreneurial community there that have sort of come together on their own. I am seeing that in Oklahoma where our company is currently based. I think that ARPA–E it provides an umbrella to bring all of those resources together in one particular area so I can go to one resource to leverage the investment community, the entrepreneurial community, or the technical community. And I think in terms of this conference that they are putting it together. The one missing piece that concerns me is bringing the likes of DuPont or the larger industrial customers into it. The companies that you mentioned that have had issues in our neck of the woods are not always aware of the entrepreneurial startup community or how to interface with them. So I think whether it is the forum that Dr. Majumdar is sponsoring or through entrepreneurial economic development in the local area, you really need to find a forum to jam everybody together to talk about these issues because as an entrepreneur in a company at our stage, I am as concerned with basic operating risks of power outages at our facilities

as I am of what customers are going to adopt our products down the road. So having a resource like that that brings it together is critically important.

Dr. MAJUMDAR. Congresswoman, that is a very important question for our whole Nation. If I look at, let us say the Bay Area, where I am from, or look at Boston, there is an ecosystem that exists with people with knowledge, knowledge-based from the universities, et cetera. There is an entrepreneur ecosystem out there, there is manufacturing, et cetera. So that ecosystem is extremely important to create the kinds of jobs and the technologies locally.

So let me tell you a few things we are specifically doing. We just had a meeting yesterday with what are called regional innovation clusters. These are the Great Lakes Association, Boston Association, from the south, et cetera. And they wanted to meet me individually, and I said, why don't you all come together. And we had a meeting yesterday to say, let us look at the best practices that are there and more so with the advanced ones, Boston and the Bay Area, and see how can those best practices be used locally and create that infrastructure so that start-up companies and all can actually flourish? And in the Energy and Innovation Summit that I mentioned, we are going to have a panel just on that. So how do we create that ecosystem in other parts of the country, not just in Silicon Valley and Boston.

Dr. ATTI. If I could add to that, I think what ARPA–E has demonstrated is the venture capital community will go beyond its traditional coastal boundaries to invest in interesting and innovative ideas. So the money is willing to go there, it is building that ecosystem that Dr. Majumdar mentioned where you bring the people and the local resources into it. So money will follow an innovative idea. So we are seeing that through this program. That is one very, very critical element that we can then follow up on.

Ms. DAHLKEMPER. I thank you very much. My time is up.

Chairman GORDON. Thank you, Ms. Dahlkemper. Sounds like you need to have someone at that summit from home. Dr. Ehlers is recognized.

A HISTORICAL CONTEXT AND PROTECTING DOE'S OVERALL EFFECTIVENESS

Mr. EHLERS. Thank you, Mr. Chairman, and I want to reassure you and defend you. I am sure that DuPont did not build their plant near your district because of you. It is clear to me that what they were taking advantage of is this mammoth potential workforce of people in Tennessee who have experience in backyard stills, and so you didn't have to train these people very much to switch over to seaweed. My apologies, Mr. Chairman.

Just a question, a rather broad question that Dr. Vest and Dr. Majumdar might want to comment on. If you look at when the Department of Energy was created in 1977, it was to undertake responsibility for long-term, high-risk research and development of energy technology, Federal power marketing, energy conservation, nuclear weapons program, energy regulatory programs and a central energy data collection and analysis program. It is a very broad agenda, but I think it fell on bad times for a number of reasons. I think the nuclear weapons program was the only one that has

ever really gotten all the money it ever needed, and I worried when we passed the ARPA–E I was very skeptical about it because I thought it might weaken the Department of Energy's programs even more than they had been weakened by a lack of funding or a lack of good direction from certain secretaries over the years. And I think back to the glory days when Glenn Seaborg, Nobel Prize winner, really got things off to a kick-start. I suspect that was probably when it was still the Atomic Energy Commission rather than the Department of Energy. But I have just seen it go downhill in a lot of ways over the years. They have their stellar accelerator projects and that, but I think much of the original intent in '77 was lost.

I was afraid that ARPA–E might in fact hurt the department even more by taking the research away and putting it outside.

It appears that is not happening. It appears that this is in some ways innervated, the Department of Energy, to engage in its research more seriously and try and tackle these problems that are on the 1977 list. Am I deluding myself with that or is that in fact happening? Is there a new spirit at the department, and if so, is he part of the reason or is having a Nobel prize-winning physicist running it the reason? I would just appreciate some comments so we can evaluate well whether or not we did the right thing with ARPA–E and whether or not we set it up properly.

Dr. VEST. Let me open, Mr. Ehlers, with my comment on origins and then obviously Dr. Majumdar can speak to the current situation.

The Department of Energy started off and built as is absolutely inevitable into a large, bureaucratic organization. It has got a huge scope of responsibility, just as, by the way, the Department of Defense had done back in the '50s and '60s. And so the Rising Above the Gathering Storm Committee really saw ARPA–E as a small organization that could frankly be a bureaucracy buster, that could do things in new and different ways, and we hoped that that would not only directly accomplish its purposes by supporting and building the kind of innovation ecosystem around our universities and entrepreneurial organizations and so forth, but also infect the Department a little bit. We never saw it as diminishing the stature or importance of the core elements of DOE. But I think bringing new players to the table, generating a new excitement, getting innovators to address the energy problem who were unwilling or unable to go through the more traditional routes is what ARPA–E ought to be all about. And I think they are off to a great start in that regard.

Dr. MAJUMDAR. If I may just take a shot at this question: first of all, I am a proud former colleague of Glenn Seaborg at Berkeley. I have been funded by the Basic Energy Sciences [BES] of the Office of Science pretty much all my career, and I understand what their role is. And this is about basic science, understanding matter, and the interaction of matter and energy, and perhaps just exploring that. And I worked for the Applied Offices as well, and they have a tremendous role to play. What ARPA–E can do, for example, is that if there is a discovery in the Office of Science and that discovery has relevance for the market, how to create a technology in a very rapid accelerated fashion so that the businesses can look

at that and so that, aha, this is interesting. We can actually create a business out of it. That is the kind of role that ARPA–E can play to accelerate the process. To be honest, the Secretary is a huge reason why we are all here. He has led the way, and that is one of the reasons I am here as well. And we have, as Mr. Chairman pointed out, we are calling ourselves the band of brothers and sisters because that is the sense of mission and freshness that is there right now, and ARPA–E is being used as one of the instruments to see whether something actually works in a rapid manner and perhaps look at that as best practices for the rest of DOE.

Mr. EHLERS. Just one other aspect of this I want to mention. I am very glad to hear that, and I hope it continues to go that way.

THE STRUCTURE OF ARPA–E'S GRANT SYSTEM

In the awarding of grants, one government agency that has been doing this for years and has done it extremely well is the National Science Foundation. Did you or have you followed the model of the foundation? Did you work with them in establishing this to try to set up a good system or did you develop one that was completely independent?

Chairman GORDON. Dr. Ehlers, if you don't mind, he will have to get back with you on that. We are getting ready to have votes, and I would like to try to—you are two minutes over, if you don't mind——

Mr. EHLERS. That is fine.

Chairman GORDON. —so we could move. Mr. Wilson, you are recognized.

CRITERIA FOR FUNDING OPPORTUNITY ANNOUNCEMENTS

Mr. WILSON. Thank you, Mr. Chairman. Thank you, gentlemen, for having our group here today that we can discuss these issues with.

My first question is to Dr. Majumdar. What criteria do you feel is different in the ARPA–E funding opportunity announcement of May 2009 versus December of 2009? And if I could put a third part on that, what changes if any in the criteria are anticipated in the third opportunity?

Dr. MAJUMDAR. I think that is a very good question. The criteria that we are using in ARPA–E is that, number one, is it a potential game-changer? Is it new? If it succeeds, will it change the ballgame in terms of reducing our imports of oil, of greenhouse gas emissions and will it provide technological lead for the United States? So these are the criteria we are using. And I think this is sort of universal, across the board. The other things that we are also considering are, is it white space? Is it an area where DOE has never gone before but is absolutely critical? For example, grid-level storage. This is an infrastructure which does not have a bank, and we need that and that could make the grid much smarter than what we are proposing today. So that is an area that we got into. Electrofuels is another area where it hasn't been conceived, even. So that is the criteria that we are looking at is where is the white spaces, where are the gaps in the market that we could enter and whether it is transformational or not.

ECONOMIC RECESSION AND INNOVATION

Mr. WILSON. I see. Thank you. The second question I have, Dr. Vest, you and Dr. Denniston made some very good points about how far behind we are in innovation and what we really need to be doing, especially in the amount of engineering graduates that we have in America today. We were told this a year or so ago by Bill Gates when he came for a visit saying, you know, American needs to get in the game, and we need to understand it.

Do you feel that the financial crisis that we are in now in our country has impacted our ability to do the innovation, to create the engineering group that we need? Maybe I would do that to Dr. Denniston if I can?

Mr. DENNISTON. Absolutely. Yeah, the financial crisis has affected everything in the economy. If you look at budgets—I will let DuPont speak to this—but there are budget impacts across the board. And so I think it is a challenge for a lot of reasons. Markets have been impacted. That affects research and development budgets.

Having said all of that, from our perspective as a venture capital investor, the entrepreneurs are still coming up with wonderful, wonderful ideas. We are more excited now than we have ever been about the innovation potential, not just in renewable energy but in information technology and the life sciences. If I could share with you the details of what we are seeing and the great entrepreneurs that we are just privileged to be able to interact with, we have more than a chance. We have a great chance. And what they lack mostly now is the funding to give them the encouragement to go and invent.

Chairman GORDON. Mr. Wilson, if you don't mind, we have got votes on, and I would like to be able to move on.

Mr. WILSON. That is fine.

Chairman GORDON. In order that they were received, Ms. Giffords, Mr. Garamendi, and Ms. Edwards, so maybe if each of you could try to do one question and we could all get it in?

ARPA–E AND THE GLOBAL SOLAR POWER MARKET

Ms. GIFFORDS. Great. Thank you, Mr. Chairman, and to our panelists, what a terrific opportunity to hear from our experts.

I am a big fan of ARPA–E, and I am really excited about the possibilities. I don't think the general public quite understands the potential of ARPA–E, but I come from the sunny State of Arizona. Very passionate about solar energy. So I would just like a couple of folks, but particularly Dr. Majumdar, to talk about a ARPA–E's project with solar and then if someone could talk about the fact of where we are in the global solar market, where we all complain about importing oil from foreign countries, mostly hostile countries, but now we are in the process of importing solar panels from other countries like China. So please, Dr. Majumdar.

Dr. MAJUMDAR. Thank you very much. I actually lived in the State of Arizona for three years, and I loved it. So I really enjoyed——

Ms. GIFFORDS. Well, please come back.

Dr. MAJUMDAR. So in the solar area, I think there is a tremendous opportunity. Let me just explain a little bit of a technical matter. Solar cells today, if you look at the whole balance of system and the cost of installation, it is about $3 or $4 per watt. And if you can bring the cost down to about $1, $1.50, then the scalability will be obvious.

So the question is, where is the major cost? Some of it is materials cost. If you can make thin films and single crystals, then it is high efficiency, and that efficiency reduces the balance of system cost. The other is the balance of system cost of power electronics, et cetera, and those things. For example, in the United States, we have lost the art of power electronics. We invented it out here. It has gone elsewhere. So we are having a workshop on February 9 on power electronics and how to create, how to use our innovation to create smart modules, which are much lower cost and that will enable the impedance matching in the solar cells photovoltaic devices, et cetera.

So that is the kind of thing we are trying to do. I think it is extremely important to bring down the cost so that it scales up.

Chairman GORDON. Ms. Giffords, is it OK if we go to Mr. Garamendi?

FUNDING CONSTRAINTS AND NATIONAL SECURITY

Mr. GARAMENDI. I have got about 25 hours of questions. Extraordinary panel, terrific testimony. I think I am just going to really shorten this. This is really about national security in the most fundamental way, and every way you can consider it, and I won't go into all the details, but it is also about the allocation of resources. We just heard from the President we are going to have a no increase in the discretionary budget. This is a discretionary budget. You are zeroed out. ARPA–E doesn't exist after this second round of money. It is gone. And the question that we are faced with is where to put the money. Are we going to put $30 billion more money into Afghanistan with perhaps national security or are we going to put money into this? These are the questions we are faced with. We are spending $10 to $15 billion a year subsidizing an extraordinary industry, the oil industry. We have done it for a century. Why in the world are we continuing to do that? Money needs to be moving to those things that create future national security, and that is where you are. You can comment all you want. You need to know where I am coming from. This is where we need to put our money into this secondary stage, moving from the basic research into the venture capital sector and then beyond. We also need to make sure the money flows into the valley of death.

So these are where the subsidies need to go. I don't want in this process to forget about the basic research that is being done at the laboratories, the university campuses as well as the laboratories, and this is the next stage moving it out of there. A lot of things need to be done. We don't have time to get into it. My comment, I would love to talk to you about it in detail. I guess we are going to go.

Chairman GORDON. Yeah, I think this panel would agree with you, and so if it is OK——

Mr. GARAMENDI. Well, let us do it.

Chairman GORDON. Let us move to Ms. Edwards.

Mr. GARAMENDI. You have got 10 votes here, what more do we need?

POTENTIAL CHANGES TO FOAS AND THE NEED FOR INVESTMENT

Ms. EDWARDS. Thank you, Mr. Chairman, and I appreciate being able to bring up the rear here. And thank you all for your testimony.

My question actually has to do with the first set of awards, 37 awards, spread out over the range, and I wonder if you have any questions or concerns as you think about the future. I think we got to figure out the money question for the future but of ARPA–E as to how you might spread that differently, what you might do differently in the process actually to reach, for example, minority serving research institutions, to spread out the range of types of small businesses that you are reaching. And I wonder, I think Mr. Denniston, if you could talk to me about the limitations of venture capital which underscores why we need to make a Federal investment in ARPA–E and innovation in research and technology? Dr. Majumdar first.

Dr. MAJUMDAR. I think the first round of the funding opportunity announcement was an open round, let us see what is out there in terms of ideas. And the second round that we are doing is more focused, and that has come about because of our workshops. And so it is the workshops that will bring people from different communities and bring them together so that we allow them to team together. And then they can form teams and actually compete.

So that is the process that we are following, and maybe down the line we could have a few open ones as well because who knows, maybe there is an idea that doesn't quite fit into these boxes that we are creating. So that is something that we plan to do.

Ms. EDWARDS. Well, I just want to also draw your attention, Bill Gates had a blog post, and in that blog post he said, you know, basically, what are we doing here? I mean, the future is in this kind of innovation, and we are way behind the curve, and we don't have any money in it. And so I think, again, that underscores what you are trying to do with this program in terms of, you know, not let the 1,000 flowers bloom because I understand risk-taking. But there is a fair amount of risk-taking here, and that should be OK with us.

Dr. MAJUMDAR. Yes, I agree with you.

Ms. EDWARDS. Mr. Denniston?

Mr. DENNISTON. Yes. A wonderful question, again, Representative. The role that the venture capital industry has traditionally played in information technology in the life science industries is to look to invest in the phase after a technology's highest risk phase has been removed. That is what venture capital partnership investors are looking for, high probability results, higher technologies that have established a proof of principle. And so the challenge that the investment community in America is facing today, I use my baseball metaphor from before, is America isn't getting enough at-bats for renewable energy because the funding at the Federal level is dangerously deficient. The rest of the world is hitting home

runs, we are way behind in market share, and if we don't find the funding, we will slip further.

Ms. EDWARDS. And I heard your comments there about, you know, concerns around protectionism in terms of how you are moving and investing in these technologies. But I want to just draw your attention, I think a couple of months ago the *Financial Times* did a series about the kind of investment that Germany is making, deep financial investment, in lithium battery production. It is not protectionism. It is saying, you know, this is our money, this is our market. Let us grow it.

Mr. DENNISTON. Yeah, let me elaborate if I may for a minute on that.

Chairman GORDON. Or less.

Mr. DENNISTON. Thirty seconds. The notion raised earlier is that we have to string our funding so that manufacturing can't go overseas. I think if we do that, as in tariffs, we can expect other countries to respond in kind. One of America's major assets is our entrepreneurs. And so if that is a result, then our entrepreneurs won't be able to license great technologies from overseas, and I would strongly suggest that Congress and this Committee think about that before we put strings on funding.

Chairman GORDON. Mr. Denniston, we are in the ninth inning, and there are two minutes and 39 seconds left before we have to go before votes are concluded. So let me thank this Committee. I think you have made some good progress, and I will also say that the record will remain open for two weeks for additional statements from Members and for answers to any follow-up questions the Committee may ask of the witnesses. The witnesses are excused, and again, thank you for coming.

[Whereupon, at 11:46 a.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Arun Majumdar, Director, Advanced Research Projects Agency–Energy (ARPA–E)

Question submitted by Representative Ben R. Luján

Q1. Dr. Majumdar, thank you for testifying, the work you have done with ARPA–E in this short time is very impressive. In your testimony, you state that you would like to encourage many of the teams who did not get funded to return to ARPA–E with their ideas for future programs. Can you elaborate on what role you would like regional or geographical diversity to play in future funding opportunities and programs?

A1. ARPA–E does not consider regional or geographic diversity as a factor in evaluating or selecting proposals. Our mission is to fund the best ideas, regardless of their origin. Still, ARPA–E's recipients and subrecipients are located in nearly every state in the U.S.

ARPA–E has invited many of the teams which were not selected for funding to participate in our technical workshops. Some of these workshops have led to new programs, and these teams have submitted proposals. We also invited teams that did not get funding to showcase their technology at the ARPA–E Energy Innovation Summit (held in March 2010), and many of them used that opportunity.

Some have suggested that we should organize regional mini-summits around the country to bring together local technical, entrepreneurial and investment communities. We are considering this idea. And, ARPA–E has begun to work with regional energy innovation clusters and other regional groups in more than a dozen states to support the development of energy technologies, similar to the highly productive regional clusters which formed around and encouraged growth in the information technology and life sciences sectors.

Questions from Representative Bob Inglis

Q1. Have you experienced significant overlap between your program and existing programs at DOE? Has this been problematic for deciding which types of projects to support?

A1. We have not experienced significant overlap between ARPA–E's program and other programs at DOE. ARPA–E has a fundamentally different mission and function from other DOE programs: ARPA–E focuses on breakthroughs in technology; it funds the development of transformational energy technologies with high technical and market risks, but short-term R&D potential for game-changing results. For example, one ARPA–E project seeks to convert an aluminum manufacturing process into a liquid metal battery for grid-level electricity storage—this approach is too application-oriented for the Office of Science and too high risk for applied energy offices.

I would add that as ARPA–E organizes workshops, creates new programs and reviews proposals, we engage the relevant people from the Office of Science and the applied energy offices. This helps us avoid significant overlap between ARPA–E and other DOE programs, while allowing us to benefit from the expertise of other programs within DOE.

It is helpful to differentiate ARPA–E's mission with the other two most closely related DOE initiatives—Energy Frontier Research Centers and Energy. ARPA–E funds small groups focused on breakthroughs in technology. ARPA–E uses a highly entrepreneurial funding model to support specific new technologies where a short-term R&D effort could deliver game-changing results. By contrast, Energy Innovation Hubs are large, multi-disciplinary, highly collaborative teams of scientists and engineers working over a longer time frame to achieve a specific high priority goal. They are led by top researchers with the knowledge, resources, and authority to nimbly guide efforts, seizing new opportunities or closing off unproductive lines of research. Energy Frontier Research Centers are small groups of researchers focused on breakthroughs in science. They are mostly university-led teams working to solve the specific scientific problems that are blocking clean energy development.

We don't know where the big energy breakthroughs are going to come from—only what has worked in the past. To reach our energy goals, we must take a portfolio approach to R&D: pursuing several research strategies that have proven to be successful in the past. This work is being coordinated and prioritized, with a 360 degree view of the pieces, and these pieces fit together. Discovering new energy solutions will take smart collaborators pushing the frontiers of science. It will take risk-takers

working out of their garages. It will take robust research teams on a mission. And it will take a Department of Energy that brings together the different parts of this research strategy to accelerate the innovation process.

Q2. I have corresponded with Assistant Secretary Zoi about an innovative wind turbine designed by a constituent of my district. We agree that ARPA–E is an excellent platform for further research in this design. Is ARPA–E going to issue a funding opportunity announcement to support wind energy in the near future?

A2. ARPA–E is considering issuance of an open funding opportunity in FY 2011 which, like ARPA–E's initial FOA, would allow proposals for any technology, including innovative wind turbines. We plan to hold workshops on high impact areas to determine if there are specific technological barriers around which we might structure a future funding opportunity announcement.

Questions from Ranking Member Ralph M. Hall

Q1. The statutory charge for ARPA–E states that its goals should include pursuing energy technologies that (a) reduce our dependence on foreign energy and those that (b) reduce greenhouse gas emissions. Recognizing that there is some overlap between these goals—as you noted during hearing Q&A period—how do you prioritize between them? That is, if all other things are equal, how would you weigh the potential of a project to improve energy security versus its potential to reduce greenhouse gas emissions?

A1. Pursuant to its statute, ARPA–E prioritizes projects that will enhance the economic and energy security of the U.S. and ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies. ARPA–E evaluates all proposals against these objectives. ARPA–E is investing in a portfolio of technologies that could work in synergy and address multiple goals. For example, ARPA–E is investing in next-generation batteries for transportation that could allow U.S. leadership in hybrid electric vehicles. But, these electric vehicles would also significantly increase demand for electricity. So, ARPA–E is also investing in new carbon capture technologies that could allow cleaner production of electricity from domestic coal. The combination of batteries for hybrid vehicles and carbon capture from coal power plants will enable the U.S. to: (i) use an increasing percentage of electricity for transportation, while decreasing dependence on imported oil; (ii) secure U.S. technological leadership in electric battery manufacturing; (iii) allow increased use of domestic coal for electricity generation with reduced greenhouse gas emissions.

ARPA–E will look at our overall portfolio with the goal of creating programs and funding projects which will provide economic and energy security while simultaneously securing technological leadership. Since the major economies of the world (e.g., China) are heavily investing in clean energy technologies that reduce greenhouse gas emissions, any new APRA–E-funded clean energy technology would help the U.S. gain competitive leadership and enhance our economic security.

Q2. In pursuing ARPA–E's statutory goal to reduce dependence on foreign energy, how much focus have you given (or will you give) to supply-side technologies that increase or enhance domestic energy development and production—including fossil fuels such as oil and natural gas—as opposed to those that reduce demand through increased efficiency, etc? How many proposals did you receive in this area, and what kind of priority did the topic receive in the evaluation process?

A2. Pursuant to its statute, ARPA–E prioritizes projects that will enhance the economic and energy security of the U.S. and ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies. Nearly one-third of ARPA–E's projects are intended to enhance domestic energy development and production. For example, ARPA–E is funding the development of an innovative thermal-mechanical drilling technology that will increase drilling rates up to 10-fold relative to conventional drilling technologies. This increase in drilling efficiency will result in a significant reduction in drilling costs.

In addition, ARPA–E is funding the development of a novel process for separating useful elements from refinery off-gas (ROG). It is difficult and expensive to separate the useful elements in ROG, so refineries typically burn the ROG rather than putting it to productive use. Because of the sheer scale of refining in the U.S., even seemingly insignificant inefficiencies add up to massive losses of potential fuel. This new process could allow 42 percent of ROG to be converted into approximately 46 million barrels of gasoline per year.

Q3. A concern with the ARPA–E legislation in 2007 was its apparent vagueness of mission, particularly as it related to the various stages of research and the other R&D programs within DOE. Now that you are up and running, how would you characterize the mission and scope of ARPA–E in this context? Do you expect to primarily fund basic and foundational research, or early- or late-stage applied research, or commercialization, and what other criteria will drive the balance of your portfolio?

Related to this, what funding criteria has been developed as part of the requirement in section 501(e)(2) of the legislation authorizing ARPA–E, and when do you expect to complete the strategic vision roadmap required by section 5012(g)(2)?

A3. ARPA–E has a fundamentally different mission and function than other DOE programs. ARPA–E focuses on breakthroughs in technology. ARPA–E uses a highly entrepreneurial funding model to support specific new technologies that have high technical and financial risks, but where a short-term R&D effort could deliver game-changing results. For example, an ARPA–E project is converting an aluminum manufacturing process into a liquid metal battery for grid-level electricity storage—this approach is too application-oriented for the Office of Science and perhaps too high risk for applied energy offices. This is what we define as the ARPA–E "white-space." Recipients of ARPA–E funding include consortia of small businesses, universities, nonprofits, and others. Energy Innovation Hubs are large, multi-disciplinary, highly collaborative teams of scientists and engineers working over a longer time frame to achieve a specific high priority goal. They are led by top researchers with the knowledge, resources, and authority to nimbly guide efforts, seizing new opportunities or closing off unproductive lines of research.

We don't know where the big energy breakthroughs are going to come from—only what has worked in the past. To reach our energy goals, we must take a portfolio approach to R&D: pursuing several research strategies that have proven to be successful in the past. This work is being coordinated and prioritized, with a 360 degree view of the pieces, and these pieces fit together. Discovering new energy solutions will take smart collaborators pushing the frontiers of science. It will take risk-takers working out of their garages. It will take robust research teams on a mission. And it will take a Department of Energy that brings together the different parts of this research strategy to accelerate the innovation process.

By contrast, other DOE programs, such as Energy Frontier Research Centers, focus on breakthroughs in basic science. EFRCs, for example, consist of small teams of academics and others who work to solve specific scientific problems that are blocking clean energy development. As an example, one EFRC is working to improve our scientific understanding of the chemical reactions in battery electrodes.

Pursuant to its statute, ARPA–E prioritizes projects that will enhance the economic and energy security of the U.S. and ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies. ARPA–E evaluates all of the proposals that it receives to determine whether they will achieve these objectives.

ARPA–E intends to complete the strategic vision roadmap by December 15, 2010.

Q4. Please elaborate upon an clarify your comments from the hearing regarding the tools available to and used by your office to encourage that technologies developed through ARPA–E funding are manufactured domestically, and, more generally, how we can best ensure that the benefits of ARPA–E-funded activities go to American citizens. More specifically, are there any restrictions that prohibit companies from manufacturing products developed through ARPA–E support outside of the U.S., and if so, what is the legal origin of these restrictions?

A4. ARPA–E requires small businesses to manufacture substantially in the U.S. any products used or sold in the U.S. that embody subject inventions (i.e., inventions that were first conceived or reduced to practice under the award). If the small business assigns or licenses intellectual property rights relating to the subject inventions, the assignees or licensees are required to manufacture substantially in the U.S. any products used or sold in the U.S. that embody the subject inventions.

ARPA–E requires large businesses to manufacture substantially in the U.S. any products that embody subject inventions, whether they are used and sold in the U.S. or overseas. If the large business assigns or licenses intellectual property rights relating to the subject inventions, the assignees or licensees are required to manufacture substantially in the U.S. any products that embody subject inventions, whether they are used and sold in the U.S. or overseas.

In both of the above circumstances, an award recipient for good cause may negotiate alternate legal obligations that provide a net benefit to the U.S. economy.

These requirements exceeding any U.S. manufacturing requirements contained in any statute such as the Bayh-Dole Act or any other related Federal laws, or DOE regulations. They are reflective of DOE policy choices intended to maximize the benefit to the U.S. economy.

Q5. What steps are you taking to ensure potential conflicts of interest in your proposal review and selection process are appropriately identified and addressed?

A5. ARPA–E requires all individuals who participate in the evaluation and selection of proposals to perform their duties with the highest standard of integrity and to avoid any actual or apparent conflicts of interest. ARPA–E requires all external individuals involved in the evaluation and selection of proposals to certify that they do not have potential conflicts of interest with any proposals. ARPA–E also requires these individuals to complete a nondisclosure agreement. Internal reviewers are subject to the conflict of interest statutes and regulations. They file financial disclosure reports and have received guidance from the Department's ethics officials concerning any conflicts that they may have.

ARPA–E works closely with reviewers to identify potential conflicts of interest. Both internal and external reviewers are not allowed to access, review, or discuss any proposals for which they have potential conflicts of interest. ARPA–E's online review portal only allows reviewers to access and review proposals for which they do not have potential conflicts of interest. Both internal and external reviewers are also screened from discussions involving proposals for which they have potential conflicts of interest.

Question from Representative Adrian Smith

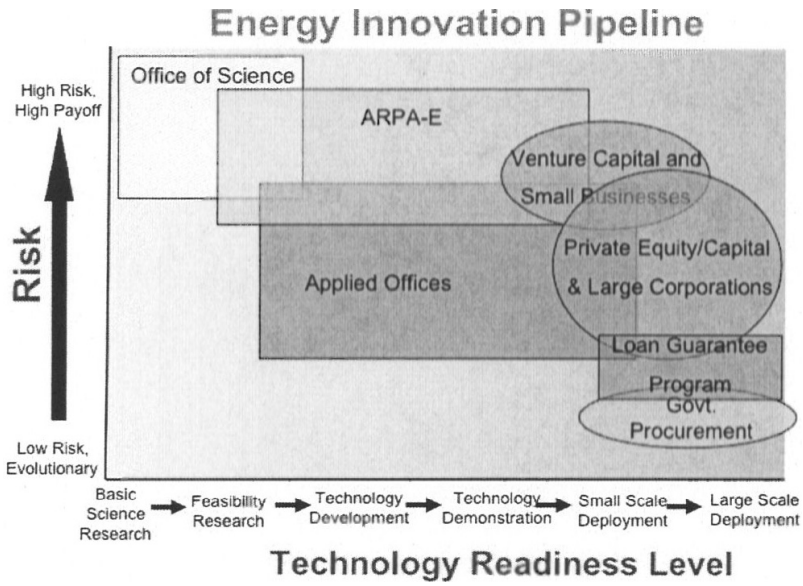
Q1. The law establishing ARPA–E states that it should pursue "high-risk" technological advances "in areas that industry by itself is not likely to undertake". This seems appropriate, and will presumably ensure that tax dollars don't compete with venture capital or other private equity, but rather are focused on advancing technologies through the "valley of death" that is too risky for private investment.

Do you agree with this philosophy, and if so, what steps are you taking during the application and review process to ensure tax dollars are not spent on technologies where the risk is already low enough to attract private investment? Among the ARPA–E awards made thus far, did any go to companies that had already received venture capital or private equity funding to pursue the technology for which it received an ARPA–E award?

A1. I do agree with the philosophy outlined in the ARPA–E authorizing legislation. ARPA–E has a rigorous process for evaluating and selecting proposals. For its first funding opportunity, ARPA–E evaluated over 3,700 concept papers, and selected only 37 submissions for award. ARPA–E does not fund applications that are deemed to have low transformational value, meaning incremental improvements on existing technology. ARPA–E does not seek to ascend existing learning curves; instead, ARPA–E seeks to create entirely new learning curves. These types of projects have high technical and/or market uncertainty, and are not being funded by industry.

We meet and communicate regularly with venture capitalists and other private investors to get a sense of their appetite for risk and the types of projects they are funding and not funding. In addition, I have hired staff with background in the venture capital industry in order to make more precise determinations of the types of high risk projects that are appropriate for ARPA–E to fund.

Let me also explain through the figure below. The Office of Science funds research in basic science and, at times, feasibility of a basic idea or a concept. Private capital is generally available at Technology Readiness Levels when products can be made based on a technology, and customers are ready to buy such products. Therefore, from the concept feasibility stage to the product development stage, a big gap exists today where many good ideas perish because the concepts cannot be translated into technologies. When these technologies are disruptive and could make today's approaches obsolete, this translation of ideas to technology is too risky both for the private sector and the applied science offices in DOE, especially. ARPA–E's goal is to invest in translating such ideas and concepts into disruptive technologies and helping to make them market ready. Furthermore, ARPA–E will invest in multiple disruptive technological approaches to reach the same goal (e.g., high energy density, low-cost batteries for plug-in hybrid vehicles), and then let the private sector pick the winning technology based on what is best for business. Hence, ARPA–E's goal is to reduce technological risks at various stages of developing disruptive technologies.


Energy Innovation Pipeline
High Risk, High Payoff
Risk
Low Risk, Evolutionary
Office of Science
ARPA-E
Venture Capital and Small Businesses
Private Equity/Capital & Large Corporations
Applied Offices
Loan Guarantee Program
Govt. Procurement
Basic Science Research
Feasibility Research
Technology Development
Technology Demonstration
Small Scale Deployment
Large Scale Deployment
Technology Readiness Level

ANSWERS TO POST-HEARING QUESTIONS

Responses by Chuck Vest, President, National Academy of Engineering

Questions submitted by Ranking Member Ralph M. Hall

Q1. As you know, the highest priority recommendation for research in the National Academies' "Gathering Storm" report was to increase funding for long-term basic research in the physical sciences—including the Office of Science at DOE—by 10 percent annually. In testimony before the S&T Committee in 2006, Gathering Storm committee member and then-Lawrence Berkeley national lab director Steven Chu stated that: "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% per year over the next seven years."
In your opinion is this recommendation still valid, and should the Office of Science remain the top research funding priority at DOE?

A1. In my view, the DOE Office of Science should remain a high priority for funding, but so should ARPA–E. The Department of Energy (DOE) faces the enormous challenge of bringing new science, new technology, and above all, new players to stimulate and enable a national commitment to produce safe, secure, clean, and affordable energy in the 21st century. It must do so with full recognition that new scientific breakthroughs are needed, that such scientific breakthroughs must be translated into technologies that ultimately must be selected and implemented by the private sector, and that it is doing so within a DOE R&D budget that in real dollars is approximately 50 percent of what it was 30 years ago.

Secretary Chu has approached this challenge by structuring an integrated approach to DOE research across fundamental physical science (Office of Science), frontier energy research (Energy Frontier Research Centers), breakthrough energy technology (ARPA–E), and large-scale multi-sector energy R&D (Energy Innovation Hubs). In my view, this integrated approach is both balanced and bold. The Office of Science funding provides America's "seed corn" of fundamental physical science as well as use-inspired basic science research that provides the foundation for transformational energy technology development. The Office of Science articulates well with the three integrated entities (EFRCs, ARPA–E, and EIHs) that together directly confront America's energy challenge, bringing to this task more of our best and brightest together from universities, the National Labs, the entrepreneurial community, and the business sector. It does not presuppose technological "winners," and it provides balance across the spectrum of technology challenges from those, at one end of the spectrum, that are high-risk but with potentially high payoff to those at the other end of the spectrum that are low risk but important incremental technology improvements to help accelerate commercial adoption with many shades in between the two ends of the spectrum.

To illustrate why I believe we need a new approach, and why ARPA–E was the sole new Federal entity recommended by the Gathering Storm Committee, let me cite the Academies 2002 report analyzing the relative effectiveness of DOE's energy efficiency, renewables, and fossil energy applied research programs, *Energy Research at DOE: Was it Worth it?* This report found that only a handful of research results produced benefits far exceeding the costs of carrying out the entirety of energy projects in those areas. The challenge is that despite the best of analysis it is impossible beforehand to select the handful of technologies that will deliver major benefits. It is even more difficult to pick those basic research areas that will ultimately yield transformational change, so seeking balance in dimensions of risk, scale and time is important.

It is time for a new, balanced but bold approach, and that must include both the Office of Science and ARPA–E.

Q2. Given the reality of dramatically increased budget pressures and the President's announcement to freeze non-defense discretionary spending for the next three years, how do you recommend Congress prioritize among DOE's Office of Science, applied technology programs, Energy Innovation Hubs, Energy Frontier Research Centers, and ARPA–E? Would you support funding ARPA–E if the only way to achieve it were by cutting DOE's other technology development programs such as EERE or the energy innovation Hubs, or are those programs more important?

A1. In the previous question I outlined the essential objective of maintaining balance and boldness across the overall DOE energy R&D portfolio in terms of risk, timing, and scale. Just as in the face of a major stock market change one wouldn't or shouldn't place all investments in high risk, and potentially high payoff stocks, a strategic approach to structuring the portfolio is essential to maintaining that balance.

In my opinion, funding ARPA–E in the face of a possible discretionary budget freeze should not result in an automatic reduction in support of other components of the DOE R&D portfolio. This integrated portfolio should be thoughtfully rebalanced just as one would rebalance a stock portfolio. Meeting the energy challenge is essential to our economic viability and future employment base.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Anthony Atti, President and CEO, Phononic Devices

Questions submitted by Representative Ben R. Luján

Q1. Dr. Atti, in your testimony, you discuss the barriers you have faced to commercialization of your technology. For example, you mention market risk and state that if you build it, the customer won't always come. Can you comment on how ARPA–E can better support innovative energy research projects with commercial emphasis in order to minimize market risk and promote the commercialization of energy technology?

A1. In my experiences most government support of research and development focuses almost exclusively on technical development; namely the achievement of important scientific proof-of-concept principals. While the ARPA–E technical review was incredibly rigorous and thorough, most impressive was that almost 50% of the proposal was dedicated to business-oriented issues, including: target market size and specific opportunities; the identification of first market adopters; tangible impact on environmental remediation of either greenhouse gases or other pollutants; appropriate cost benchmarks through all stages of commercial development; and a roadmap for broad market penetration. These critical variables will help ensure that technical milestones and progress is in complete accordance with commercial expectations.

I would encourage ARPA–E to solicit input from industry leaders, end-users, and best-in-class experts so that future technology solicitations will continue to track commercial targets. Furthermore I believe that a minimum cost share from the awardee will help to ensure that technical development is consistent with commercial goals.

Questions submitted by Representative Bob Inglis

Q1. Do you see a role for ARPA–E in developing innovator-investor relationships outside of the grant issuing process? Do you think it is a reasonable goal for ARPA–E or DOE in general? If so, what would that role be?

A1. I believe ARPA–E should have the role of facilitator connecting innovators with investors outside the grant issuing process. For instance the ARPA–E summit on March 1–3rd, 2010 was an excellent example of how ARPA–E was able to provide a forum for awardee companies to profile their technologies. In this instance ARPA–E also gave space to companies that were not selected for an initial award as well; demonstrating that an award is not the only indicator of a good or investable idea. Considering that ARPA–E and the DOE have strong connections to energy-related industries and best-in-class experts I do believe that this is a reasonable goal. Too many government-supported research projects never achieve commercialization due to the fact that strategic partners are unaware of their research and/or venture capital tends to be regionalized and somewhat provincial in focus. As long as ARPA–E and the DOE avoid the appearance of choosing favorites or 'winners', conferences or summits where innovators, investors and strategic leaders of industry can attend is a worthwhile objective.

Questions submitted by Representative Adrian Smith

Q1. It seems based on your testimony that your company's technology has undergone several stages of development prior to receiving ARPA–E funding. Was that technology development funded by venture capital or other private investment, and if so, why wouldn't the private capital that supported the earlier stage development also support the shorter-term commercialization needed to get your product to market?

A1. Phononic Devices has actually not undergone several stages of technical development or funding; I apologize if I left this impression. Our company was founded in October 2008, received a $1M financing from venture investors in February 2009, and only began scientific experiments later that year. Our technology is still very early in development and represents significant technical risk; it is highly unusual for a company at our stage of development to raise any venture capital financing at this stage. Our original projections planned on prototype demonstration and subsequent first market adopter sales in late 2012 or early 2013. The ARPA–E award coupled with another $1M in venture financing as part of our required cost share

allows us to accelerate our development schedule to 2011 instead. ARPA–E represented an important independent assessment of our technology development approach and thus allowed us to better leverage private capital to accelerate time-to-market.

ANSWERS TO POST-HEARING QUESTIONS

Responses by John Denniston, Partner, Kleiner Perkins Caufield & Byers

Questions submitted by Representative Bob Inglis

Q1. Do you find it problematic that, unlike DARPA, ARPA–E does not have a specific customer for its products? In other words, do you think that the market will be receptive to ARPA–E technologies, or is the government taking on a risk better left to the private sector?

A1. On your first question, no, I don't. In my view, DARPA's key innovation wasn't to create a single-customer relationship, but rather to pioneer a model of "translational" research, in which the agency would anticipate its customer's needs—in this case, the DOD's military objectives—and direct government funds to research institutions and defense contractors, in a competitive process, to invent advanced technologies to achieve them.

This is precisely the methodology ARPA–E is now deploying. Yet instead of engaging with a single customer, ARPA–E personnel join forces with numerous potential customers and collaborators in the energy and investment industries to establish the agency's funding priorities. Even in the absence of industry feedback, ARPA–E's management is well aware the private sector will eagerly embrace innovations with obvious commercial potential, such as solar power at grid parity cost and advanced batteries that triple electric vehicle mileage. Of course, as was the case with DARPA, the innovators who win ARPA–E funding will need to demonstrate the viability of their technologies before selling products.

As to whether the Federal Government is taking on a risk better left to the private sector, I must point out that basic research funding has never been the central focus of the private sector, nor is there reason to believe that it will be in the future. Extending ARPA–E's charter would ramp up U.S. basic research for breakthrough energy technologies which are in high demand by the private sector.

Q2. Do you see a role for ARPA–E in developing innovator-investor relationships outside of the grant-issuing process? Do you think this is a reasonable goal for APRA–E or DOE in general? If so, what would that role be?

A2. I do indeed see such a role for ARPA–E, and would argue that it's more than a reasonable goal; it's a necessary one. Fortunately, ARPA–E's forward-thinking managers are already pursuing this strategy. From March 1–3 in Washington, the agency held a hugely successful "Innovation Summit," with support from the National Venture Capital Association. The meeting drew about 1,700 energy industry leaders, including researchers, investors, and entrepreneurs, from 15 countries and 49 U.S. states. The summit highlighted the agency's first round of 37 winning research projects (selected from a pool of nearly 3,700), and featured discussion about how to identify and successfully develop and commercialize game-changing technologies. By bringing innovators and investors together, the DOE and ARPA–E can catalyze energy breakthroughs, and in so doing, help secure America's energy future.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Michael A. Blaustein, Technology Director, Science and Technology Strategic Planning, for John Pierce, Vice President, Dupont Applied Sciences in Biotechnology

Questions submitted by Representative Bob Inglis

Thank you for your e-mail note to Dr. John Pierce, regarding the question that was raised by Congressman Bob Inglis at the January 27 hearing regarding ARPA–E. I am responding on behalf of Dr. Pierce who has since retired from DuPont.

Q1. Do you see a role for ARPA–E in developing investor-innovator relationships outside the grant-issuing process? Do you think this is a reasonable goal for ARPA–E or DOE in general? If so, what would that role be?

A1. The successful commercialization of breakthrough innovations in many technology arenas increasingly requires the active networking of several stakeholders, who collectively enable the translation of creative concepts into sustainable solutions. The investor community (VCs and corporations) are a natural part of such communities of interest.

ARPA–E (like DARPA) is uniquely positioned to create such productive networks. The mission and role of ARPA–E in the innovation ecosystem makes it a natural focal point for many creative ideas from many sources. Thus, ARPA–E can achieve a wider view of what is possible than most individual players. From the wide range of ideas and proposals it receives, the agency is ideally positioned to identify parties with shared interests and complementary capabilities, and to create a richer, stronger and more robust pool of technology options by enabling combinations of these interests and capabilities that go beyond the issuance of grants.

While it is important to maintain the confidentiality of specific ideas, it should be possible for ARPA–E to act both as a clearinghouse and as a matchmaker to bring together parties with shared interests, and to ensure that the innovation process—from idea generation through R&D to commercial development—takes full advantage of potential synergies between different players. ARPA–E's sister agency, DARPA, already has a reputation for being an effective enabler of such networks.

In light of the above, I strongly recommend that mechanisms should be explored that will permit ARPA–E to play this important role as an enabler of collaborative innovations. Most importantly, this facilitative role needs to be explicitly acknowledged in ARPA–E's charter. The implementation of this role is more tactical in nature. Possible actions could include workshops involving diverse groups of potential collaborators organized by ARPA–E to brainstorm specific ideas before a call for proposals is issued, or targeted meetings to discuss specific technology concepts that emerge as common themes within the proposals received in response to a BAA or FOA. This will require a lot of personal initiative and proactive matchmaking on the part of the individual program managers, but we believe this is achievable.

Appendix 2:

Additional Material for the Record

STATEMENT OF WILLIAM J. PERRY, 19TH UNITED STATES SECRETARY OF DEFENSE

Chairman Gordon, Ranking Member Hall, and Members of the Committee, I want to thank you for the opportunity to present my perspective from a different vantage point on The Advanced Research Projects Agency–Energy (ARPA–E): Assessing the Agency's Progress and Promise in Transforming the U.S. Energy Innovation System. ARPA–E is modeled after Defense Advanced Research Projects Agency (DARPA) at the Department of Defense (DOD). I should note that I have had significant experience working with DARPA. Much of the success during my tenures at the DOD and those of this country's current military strategy are due to the technologies that resulted from DARPA.

As you may know, first as Undersecretary of Defense for Research and Engineering (DDR&E) (1977–1981), as Deputy Secretary of Defense (1993–1994), and then as Secretary of Defense (1994–1997), I know first hand how instrumental research organizations like DARPA are in solving great challenges the Nation faces. DARPA was created in 1958 in response to the launch of Sputnik by the Soviet Union and that country's growing military capacity after World War II. It was meant to ensure that America would not fall behind in transformational technologies. The political and defense communities recognized the need for a high-level defense organization to formulate and execute R&D projects that would expand the frontiers of technology beyond the immediate and specific requirements of the Military Services and their laboratories. Ominously, during the Cold War, the Soviets managed to build tanks, aircraft, and guns at a rate of about three times that of the United States and by the mid-1970s, they had achieved parity in nuclear weapons as well.

The United States sought a strategy to restore the conventional military balance and this committee, along with several other Members of Congress, were key to seeing the need and creating a proposed solution. This effort was led by then-U.S. Secretary of Defense, Harold Brown, who held that position in the late 1970s. His approach was to develop high-technology systems that could give our military forces a qualitative advantage able to offset the quantitative advantage of the Soviet forces. Not surprisingly, this approach was called the "Offset Strategy." At the time, I was Undersecretary of Defense for Research and Engineering and Secretary Brown gave me the responsibility and the authority to achieve this objective.

1. The DARPA Example

Very early in my tenure, I went to DARPA for detailed briefings on evolutionary technologies that were to be the concept of the Offset Strategy. I was so impressed and saw such potential in transforming the defense industry landscape that I told the DARPA director he would have all the resources needed to prove out the concept as quickly as possible. The ultimate success of this Offset Strategy depended on three closely related components: (1) a new family of intelligence centers that could identify and locate in real time all the enemy forces in the battle area; (2) the development of "smart weapons;" and (3) the design of stealth aircraft and ships. Taken together, this new system of systems was initiated by the DARPA program and developed with the highest priority during the late 1970s, produced in the early 1980s, and entered into the force in the late 1980s, just in time for Desert Storm.

The results were nothing short of spectacular. It allowed the U.S. to change the rules of conventional warfare in a manner that many consider to be the forefront of a broad "Revolution in Military Affairs" (RMA). It also proved as a model to assemble the greatest minds in science and technology with industry and investors and bring products to the marketplace expeditiously.

2. ARPA–E

Why do I detail this example above? Because it is exactly what DOE seeks to do with the technologies discovered through ARPA–E—transform the energy landscape by focusing 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. The need for energy innovation is profound. Like DARPA was driven by the Soviets' threat, ARPA–E seeks to face head-on the challenges of (a) energy security; (b) U.S. technological lead; and (c) greenhouse gas emissions and climate change.

ARPA–E's strength as an organization is in its structure, or lack thereof. The agency owns no facilities and has no infrastructure that requires long-term programs for support. Instead, it pursues high-risk, high-payoff research through short-term projects with aggressive technical goals. Program Directors stay on for a limited amount time, and as a result there is personal pressure to advance the state of the art on very aggressive timelines that result in the engine of innovation.

ARPA–E, also like DARPA, will bridge the "valley of death" and leapfrog over today's technologies. At the time of DARPA's establishment, it was felt that the U.S. had lost its technological lead, and that the Nation needed an organization that would invest in high-risk, high-reward R&D and connect technological innovation to business, which would then support the defense industry. Today, ARPA–E is working to streamline this process for the energy sector. Its goal is to require that technologies demonstrate success sufficiently to reduce the risk for further large-scale investments.

This committee has recognized that our nation needs to invest in researchers, scientists, engineers, and technologies to address these and other global challenges. I have had the opportunity to spend time with the ARPA–E director, Arun Majumdar, and his team to understand how they are planning to build this organization, what kind of innovations they are introducing, and how they operate. I can assure you that they have certainly exceeded my expectations. In less than a year they have all the key ingredients that would place them on a road to success and they are off to a great start. While they have adopted the best practices of DARPA, they have also identified the significant differences between the defense and energy sectors of our economy, and have adapted ARPA–E to address the issues unique to the energy sector.

An initiative that is new to the ARPA model, and a program I am particularly enthusiastic about, is the ARPA–E Fellows Program. This program will utilize the nations highly energized youth in colleges and universities who are deeply engaged in energy and the environment, and allows for them to serve our nation. Today, students are breaking the barriers between science, engineering, business, law, and public policy and are working together in energy. The ARPA–E Fellows Program brings a freshness, excitement, and sense of mission to energy research that will attract many of the U.S.'s best and brightest minds—those of experienced scientists and engineers, and especially those of students and young researchers, including persons in the entrepreneurial world.

3. Conclusion

It is with this first hand experience that I write to you today about the importance of continued support of the Department of Energy's Advance Research Projects Agency–Energy. As I did with DARPA's director in the late 1970s by giving him all the resources needed to prove new defense technologies as quickly as possible, Secretary of Energy Steven Chu is attempting to do the same with ARPA–E and Director Arun Majumdar. This can only be done with this committee's support to reauthorize the *America COMPETES Act*.

If properly supported, ARPA–E can make great strides in facing the threats which, if not addressed quickly, could lead to a drain on our economy, an uncertain future of relying on other countries for our energy demands, and negative impacts to our natural resources. Time and again the combination of investment in innovation and the nation's brightest minds and can-do spirit has led to new eras of our country. DARPA has proven that the model works and investments in science innovation such as in ARPA–E could well create a modem day industrial revolution. Furthermore, I am certain ARPA–E could bring much needed engines to spur our economy and retake our position as technological leader. As Chairman Bart Gordon stated in an interview two weeks ago (*E&E Daily*, Jan. 15), "[ARPA–E] is a major innovation initiative as well as work force development . . . .Substantively, America COMPETES creates a model for an innovation agenda." I could not agree more.

Thank you again for the opportunity to submit this statement for the record. I hope that my comments will be useful to the committee.

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