ESTABLISHING THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY (ARPA–E)—H.R. 364

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

APRIL 26, 2007

Serial No. 110–22

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE
34–719PS WASHINGTON : 2007

For sale by the Superintendent of Documents, U.S. Government Printing Office
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ESTABLISHING THE ADVANCED RESEARCH PROJECTS AGENCY–ENERGY (ARPA–E)—H.R. 364

THURSDAY, APRIL 26, 2007

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

The Subcommittee met, pursuant to call, at 2:00 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Gabrielle Giffords [Acting Chairwoman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
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Subcommittee on Energy and Environment

Hearing on

"Establishing the Advanced Research Projects Agency-Energy (ARPA-E) - H.R. 364"

2318 Rayburn House Office Building
Washington, DC

Thursday, April 26, 2007
2:00 p.m. – 4:00 p.m.

Witness List

Mr. William B. Bonvillian
Director, Washington Office, Massachusetts Institute of Technology

Mr. John Denniston
Partner, Kleiner, Perkins, Caufield & Byers

Dr. Stephen R. Forrest
Vice President for Research, University of Michigan

Dr. Richard Van Atta
Research Staff Member
Science & Technology Policy Institute

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Establishing the Advanced Research Projects Agency–Energy (ARPA–E)—H.R. 364

THURSDAY, APRIL 26, 2007
2:00 P.M.—4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, April 26, 2007 the House Committee on Science & Technology, Subcommittee on Energy and Environment will hold a hearing to receive testimony on H.R. 364, *Establishing an Advanced Research Projects Agency for Energy.*

Chairman Gordon introduced H.R. 364 on January 10, 2007. H.R. 364 follows on the recommendation of the National Academies of Science report, *Rising Above the Gathering Storm,* which called for establishing a new energy research and technology development agency within Department of Energy patterned after the successful Defense Advanced Research Projects Agency (DARPA) within the Department of Defense. H.R. 364 establishes such an agency, known as the Advanced Research Projects Agency for Energy, or ARPA–E.

This hearing will seek to address the following issues relating to H.R. 364:

- What are the limitations of the current energy R&D enterprise in addressing the most pressing energy-related challenges? Is ARPA–E as laid out in H.R. 364 structured to address these limitations?
- Which areas of energy research should be explored by ARPA–E?
- What organizational elements of DARPA make it an attractive model for energy research and technology development? Are there advantages and drawbacks of other organizational models that should be examined in developing an ARPA–E?
- Does the level of investment prescribed in H.R. 364 match the magnitude of challenges in energy research and development?

Background

H.R. 364 establishes the Advanced Research Projects Agency–Energy (ARPA–E), and sets up an Energy Independence Acceleration Fund to conduct activities under the Act. H.R. 364 was first introduced as H.R. 4435 in the 109th Congress. In the 109th Congress the House Committee on Science held a hearing on March 9, 2006 examining the concept of an ARPA–E (HOUSE REPT. 109–39). H.R. 364 follows on the recommendation of the National Academies 2005 report, *Rising Above the Gathering Storm,* also known as the "Augustine Report" for its chair, retired Lockheed Martin CEO Norman Augustine. This report called on the Federal Government to create a new energy research agency within Department of Energy patterned after the successful Defense Advanced Research Projects Agency (DARPA) within the Department of Defense. Several similar bills calling for an ARPA–E have since been introduced in both the House and Senate (including S. 696 and S. 761).

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. ARPA–E would accelerate the process by which research is transformed to address economic, environmental, and security issues. It would be designed as a lean, effective, and agile—but largely independent—organization that can start and stop targeted programs based on performance and ultimate relevance."

The primary motivations for establishing an ARPA–E are the need for the U.S. to obtain more energy from domestic sources, become more energy efficient, and become less reliant on energy sources and technologies that have an adverse effect on the environment. The drive for new technologies is especially urgent given the geopolitical forces that threaten global energy supplies and economic stability, the looming threat of global climate change, and probable regulation of carbon dioxide emissions. In addition to addressing the Nation's energy challenges, the *Gathering Storm* report concluded that ARPA–E should also contribute to U.S. competitiveness by playing an important role in "advancing research in engineering, the physical sciences, and mathematics; and in developing the next generation of researchers."

ARPA–E is intended to pursue energy research and technology development with a structure that is fundamentally different from the traditional energy research enterprise. Critics of the Department of Energy's management of research programs contend that the stove-piped and bureaucratic structure of DOE is not conducive to quickly developing cross-cutting energy solutions, or translating energy research into commercial technologies. ARPA–E will instead have a relatively flat organization, similar to the small, flexible, non-hierarchical reporting structure at DARPA that fostered a successful culture of innovation. Furthermore, because the director of ARPA–E reports directly to the Secretary of Energy, as is written in H.R. 364, it is not beholden to any one particular technology area or research program within DOE. To further insulate ARPA–E from bureaucratic impediments, some stakeholders have suggested that ARPA–E should not be housed within DOE at all, but may be more appropriate as an independent government corporation which can still choose to fund projects within DOE.

ARPA–E's unique role is best described as a "marriage broker" that can identify people and capabilities within industry, universities, and the national labs, and put them together in hybrid teams, coordinate research, and quickly develop novel solutions to pressing energy problems. Key to this function is the program manager. As with DARPA, these individuals would ostensibly be very talented, knowledgeable, experienced in industry, and passionate in pursuing their mission. Because of the flexible hiring authority that is written into Section 2 of the bill, talented program managers can be recruited from a variety of fields and experiences, hired for a term of approximately 2–5 years, and paid a salary commensurate with what they would make in the private sector. Program managers and their superiors are given extraordinary freedoms and resources to pursue technologies quickly, as well as freedom to just as quickly stop research if it does not look fruitful. This is probably the biggest departure from the current DOE model.

There is some disagreement on which stage of research and development ARPA–E should be focused—early stage basic research, or late stage demonstrations and commercial applications. This assumes that one is exclusive of the other, as is usually the case in the traditional energy R&D enterprise. However, a truly mission-driven ARPA–E will leverage its resources and institutional capabilities to pursue multiple stages of R&D in a "whatever it takes" approach to moving a potentially transformational technology from the laboratory bench to the marketplace. If adequately funded and directed, ARPA–E would engage in basic research into fundamental concepts with possible technology applications, and later-stage technology prototyping and large-scale demonstrations.

Both critics and proponents of an ARPA–E agree that, for the program to be successful, it must be funded at levels to match the magnitude of energy challenges, and the high costs of energy research and technology demonstration. Despite the recent attention to energy challenges, R&D investment in energy remains far below the historically high levels of the 1970's. A recent GAO report commissioned by Chairman Gordon and Congressman Honda noted that "DOE's total budget authority for energy R&D dropped by over 85 percent (in real terms) from 1978 to 2005, peaking in the late 1970's but falling sharply when oil prices returned to lower levels in the mid-1980's." (GAO–07–106) Investment in ARPA–E should be seen in the context of increasing overall energy R&D expenditures enough to truly address the challenge. The *Gathering Storm* report calls for ARPA–E to be authorized at $300 million in the first year, and quickly escalate to $1 billion within five years. H.R. 364 currently has a similar funding profile. Some suggest that the only way a high-cost, risk-tolerant program like ARPA–E would survive is if it has dedicated funding of some kind, and therefore would not be subject to annual appropriations or other political/financial pressures and resource fluctuations that stifle innovation.

Witnesses

- **Mr. William Bonvillian** is the Director of the Washington Office of the Massachusetts Institute of Technology. Previously he served as Legislative Director and Chief Counsel to Sen. Joseph Lieberman, where he worked on a wide

range of science & technology issues including those related to DARPA, and the establishment of a similar program at the Department of Homeland Security. Mr. Bonvillian will testify on the strengths and weaknesses of the DARPA model as it applies to energy research, and experiences with other models that should be considered in establishing an ARPA–E.

- **Mr. John Denniston** is a partner in the venture capital firm of Kleiner Perkins Caufield and Byers, based in Silicon Valley California, where his portfolio includes investments in clean energy and "greentech" businesses. Mr. Denniston previously served as Salomon Smith Barney's Managing Director and head of Technology Investment for Western U.S. He will address the role of the investment community in working with industry, universities, and DOE to commercialize promising energy technologies, and the policies that will spur innovation in this field.
- **Dr. Stephen Forrest** is the Vice President for Research at the University of Michigan, which recently established the Michigan Memorial Phoenix Energy Institute. Prior to joining the university, Dr. Forrest held positions at Bell Laboratories, University of Southern California, and Princeton. He will to testify on the proposed structure of ARPA–E, and how the role of university/industry partnerships can enhance energy R&D in the U.S.
- **Dr. Richard Van Atta** is at the Science & Technology Policy Institute of the Institute for Defense Analysis. Dr. Van Atta has conducted several studies on DARPA's research programs and their impact, as well as defense research projects under DARPA sponsorship. He will to testify on the organizational aspects of DARPA that fostered a successful culture of innovation.

Chairwoman GIFFORDS. I call the hearing to order. Good afternoon, everyone. It is an honor to be here today, and to have such an esteemed panel of witnesses. I also want to thank Mr. Chairman, Bart Gordon, for allowing me to step in to chair the Subcommittee hearing, instead of Congressman Nick Lampson, who unfortunately, is not with us right now, but I know he is recuperating very quickly, and will be back with us soon.

We are here today to discuss H.R. 364, the bill to establish an Advanced Research Projects Agency for Energy, also known as ARPA–E, introduced by Chairman Gordon earlier this year.

Despite passage of an Energy Bill in the 109th Congress, interest in energy, its production, its distribution, and its use, remain incredibly high. This is because we have not yet addressed the key challenges our society faces that are linked to our present energy sources and our present patterns of energy use.

We want to reduce our dependence on foreign sources of energy to ensure our economic and national security, and to improve our balance of trade. We also need to address the environmental consequences associated with the emissions of greenhouse gases from fossil fuel use that have initiated the global warming and regional climate changes that we are now all experiencing.

We must take steps to reduce our greenhouse gas emissions, and to diversify our energy sources. Part of that solution lies in getting more of the alternative energy sources and technologies to improve energy efficiency directly and immediately into the marketplace. But we must also make a greater investment in research and development to discover and to develop new energy sources, new energy-saving technologies, and new methods of reducing carbon emissions associated with fossil fuel use.

The investments that we must make must support a wide range of ideas, and foster creative thinking that will develop the full range of energy technologies. We need these technologies to continue to support a vibrant economy and the quality of life that we all enjoy today, and that is what H.R. 364 is all about.

My home State of Arizona, that I like to talk about so much, is rich in sunshine. We all know that. And solar technology has the potential to make significant contributions to our available energy resources. Within the last two years, researchers have found ways to use polymers and nanoparticles to create solar cells that capture infrared as well as visible light. With more efficient solar cells, sunshine-rich states like Arizona could exchange fossil fuel-produced electricity for electricity generated by clean, renewable solar power. We need to support this kind of creative application of nanotechnology to energy research to find the breakthroughs that will yield more than incremental improvements in current energy technologies. Also at the University of Arizona is Professor Roger Angel, who is doing a lot of innovative research on optics, using this technology to harness solar technology.

One of the recommendations of the 2006 National Academy of Sciences report, *Rising Above the Gathering Storm,* was to create an energy projects research agency, using the successful model of the Defense Advanced Research Projects Agency, DARPA, that we are all very familiar with, and that has supplied many break-

through technologies in the areas of defense, information technologies, and communications, among other things.

Chairman Gordon has taken the National Academies' advice, and incorporated their recommendations into H.R. 364. We are pleased to have a very knowledgeable and distinguished panel of witnesses with us this afternoon to offer their thoughts on the ARPA–E concept, and on how H.R. 364 can guide our efforts to achieve our goals of energy efficiency, fuel diversification, energy independence, greater economic and national security, and environmental protection.

Thank you all for being with us this afternoon. It is an honor to have you here in this subcommittee, and at this time, I will yield to the author of H.R. 364, Congressman, Chairman, Mr. Gordon.

[The prepared statement of Ms. Giffords follows:]

PREPARED STATEMENT OF REPRESENTATIVE GABRIELLE GIFFORDS

Good afternoon. We are here today to discuss H.R. 364, the bill to establish an Advanced Research Projects Agency for Energy—ARPA–E—introduced by Chairman Gordon earlier this year.

Despite passage of an energy bill in the 109th Congress, interest in energy—its production, its distribution, and its use remain high. This is because we have not yet addressed the key challenges our society faces that are linked to our present energy sources and our present patterns of energy use.

We want to reduce our dependence on foreign sources of energy to ensure our economic and national security and to improve our balance of trade. We also need to address the environmental consequences associated with the emissions of greenhouse gases from fossil fuel use that have initiated the global warming and regional climate changes we are now experiencing.

We must take steps to reduce our greenhouse gas emissions and to diversify our energy sources. Part of the solution lies in getting more of the alternative energy sources and technologies to improve energy efficiency into the marketplace.

But we must also make a greater investment in research and development to discover and develop new energy sources, new energy-saving technologies, and new methods of reducing carbon emissions associated with fossil fuel use. The investments we make must support a wide range of ideas and foster creative thinking that will develop the full range of energy technologies that we need in the future to continue supporting a vibrant economy and the quality of life that we enjoy today. That is what H.R. 364 is all about.

My home State of Arizona is rich in sunshine, and solar technology has the potential to make a significant contribution to our available energy resources. Within the last two years, researchers have found ways to use polymers with nanoparticles to create solar cells that capture infrared as well as visible light. With more efficient solar cells, sunshine-rich states like Arizona could exchange fossil fuel produced electricity for electricity generated by clean, renewable solar energy.

We need to support this type of creative application of nanotechnology to energy research to find the breakthroughs that will yield more than incremental improvements in current energy technologies. Also, at the University of Arizona, Professor Roger Angel is doing innovative research on using optics to harness solar energy.

One of the recommendations of the 2006 National Academy of Sciences Report: *Rising Above the Gathering Storm* was to create an energy projects research agency using the successful model of the Defense Advanced Research Projects Agency (DARPA) that we are now familiar with and that has supplied many breakthrough technologies in areas of defense and communications, among others. Chairman Gordon has taken the National Academy's advice and incorporated their recommendation into H.R. 364.

We are pleased to have a very knowledgeable and distinguished panel of witnesses with us this afternoon to offer their thoughts on the ARPA–E concept and on how H.R. 364 can guide our efforts to achieve our goals of energy efficiency, fuel diversification, energy independence, greater economic and national security, and environmental protection. Thank you all for appearing before the Subcommittee this afternoon.

Chairman GORDON. Thank you, Chair Giffords. I knew you would find a way to work Arizona into your statement.

Let me welcome, very warmly welcome, this distinguished panel here today. As I mentioned to you earlier, this is sort of the get-away day. We finished votes earlier, and folks often are off back to their districts. That is, I guess, the bad news.

The good news is that all of our energy staff is here, and quite frankly, you are better off talking to them than to us anyway. So, you got the folks here that are the most important in developing this bill. So, we very much appreciate you coming.

As we all know, so I won't go into it but just a little bit, approximately two years ago the former Chairman of the Science Committee, behind you there on the wall, Sherry Boehlert, myself, as Ranking Member at that time, Lamar Alexander, and Jeff Bingaman, asked the National Academies to do a report on competitiveness of America in the 21st Century. We didn't like the news they gave us, but it was realistic. They also gave us some good suggestions for the future.

Interestingly, yesterday, well, earlier, we passed unanimously out of this committee the math and science recommendations. They passed almost unanimously on the floor just yesterday. We have come out of Committee unanimously with the research suggestions, in terms of increasing the amount of funding to NSF and NIST yesterday, and they will be on the Floor next week. And so, we are moving forward, but this is an important piece of that. The other piece was, I won't say energy independence, that is going to be a little much to ask for, but to reduce our dependency on foreign energy.

And ARPA–E was their suggestion. I unashamedly plagiarized it, and we put it into legislation last year. We reintroduced it this year. You are here with us today to help us fine-tune it, to make it as good a bill as we possibly can, because it is very important for this country, and we thank you for being here.

Before this committee hearing, I set up something called Call Your Congressman. I sent out letters to about 85,000 homes to call me these next two days, and so we have been doing that, and I am going to have to go back and do some more of that.

One thing, and I am going to ask you something a little bit controversial, as you give your input. We live in a pay-as-you-go world now here in Congress, which makes things difficult. We would like to have doubled the National Science Foundation sooner than ten years. We would like to have doubled NIST in a quicker time than ten years, but we are trying, again, we are on a pay-as-you-go budget, so it is more difficult.

And so, we have to think in those terms, and one of the things that I would like to give some thought to is recoupment of some of the funds. And I know that probably you are all, in all likelihood, going to be opposed to that one way or the other, but I think that if we, in the political sense, thought almost of our investment as somewhat of a revolving fund over a long period of time, it would make it easier for us to get additional funds.

And I know this is something that is not often used, and maybe Mr. Denniston will speak to some of that. Whether there could be a way to structure the program so the Federal Government could take a share, maybe at the end. Don't you wish we had a little bit

of the Internet? We wouldn't have to do pay-as-you-go, we would just, we would have it already.

But the point is, you know, is there a way to structure this in a responsible way that does not disincentivize people from investing and getting involved in this? And that would help us, in a political sense, make it more palatable to put more dollars in up front, and it won't be a completely revolving fund.

So, in my absence, I hope that, and you can all badmouth it, because I am going to be gone, but if there is anything, you know, if there is a way, among all the bad stuff that you might think about how we might do that, just we would like to have that for that information.

And again, we welcome you all here, and thank you for joining us, and I yield back my time.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

I would like to welcome everyone to this Energy and Environment Subcommittee hearing on my bill, H.R. 364 which establishes an Advanced Research Projects Agency for Energy.

I would also like to thank our distinguished panel of witnesses for testifying. I believe your perspectives from the private investment and university communities, and your experiences with DARPA and similar technology agencies are critical to developing the most effective ARPA–E possible. I look forward to your testimony.

I first introduced this bill in the 109th Congress in response to recommendations in the National Academies report, *Rising Above the Gathering Storm,* chaired by the eminent Norm Augustine, former head of Lockheed Martin.

Along with Senators Alexander and Bingaman and others, I requested that the National Academies look into and report on the factors that threaten the U.S. global competitiveness and our leadership in technological innovation.

In addition to strengthening our education and research system, the *Gathering Storm* panel recognized that the U.S. dependence on traditional energy sources and outdated technologies puts us in a perilous position.

Not only do we face threats to our national security and economic volatility because of our reliance on unstable foreign regimes for oil and gas, we now must acknowledge that our energy use is directly tied to global climate change.

This is an untenable position, and it simply must change. Conservation is the first element in addressing this challenge. But we must also be aggressive in developing the next generation of technologies to get beyond our current energy paradigm.

The Augustine Commission recommended establishing ARPA–E, modeled DARPA's successful innovation model, to sponsor creative, out-of-the-box, transformational energy research in those areas where industry by itself cannot or will not undertake on it's own.

DARPA succeeded largely because it continued to foster a culture of innovation. We cannot legislate an agency's culture. But we can provide the resources and the institutional structure to give exceptionally talented people the opportunity to pursue high-risk, but high-payoff energy research.

A nimble organization with minimal administrative layers and the ability to quickly start and stop research programs is key to the success of ARPA–E.

As imperative as it is, transforming our energy economy is a challenge that is unfathomable to most folks. We cannot afford to wait until we face severe disruptions to fossil energy supplies or serious impacts from climate change to address this challenge.

Federal investment in energy technology R&D is down 85 percent from the 1980's. We must reverse this trend.

Investment in ARPA–E must be seen as the first step in boosting energy research and development to a level that addresses the scale of our challenge, and the true cost of doing transformational research.

We all agree that energy research and development is key to energy independence, innovation, workforce development and saving the environment.

The question is how far are we willing to go to enact real change that garners tangible results?

Establishing an ARPA–E in H.R. 364 is a bold step, but we've got to be willing to push the envelope and think outside the box to get the job done.

I appreciate the Committee's support, and look forward to the witness' testimony.

Chairwoman GIFFORDS. Thank you, Chairman Gordon. At this time, I would like to yield to our distinguished Ranking Member, Mr. Inglis, for an opening statement.

Mr. INGLIS. And I thank the Chair, and thank the Chairman of the Full Committee for holding this hearing on the establishment of an ARPA–E.

I think we share the same vision, America serving the world, and succeeding as the leading technological innovator. We also share the same goal, creating incentives for technology advancement. We share some of the same strategies and tactics toward the attainment of the goal and the fulfillment of that vision.

There may be some wisdom in setting up a separate federal agency within, or create a new federal agency within the Department of Energy to mimic the risk-embracing and entrepreneurial activities of the DARPA program. It is possible that an ARPA–E research could eventually offer big payoff in the commercial energy market. At the same time, we are seeing some payoffs coming from existing DOE research, especially in hydrogen, nuclear, wind, and solar programs. My concern is that the ARPA–E could possibly divert funds away from these existing programs, and jeopardize the advances that we are seeing in those areas. I hope that we can find a way to ensure that that doesn't happen.

Also, unlike DARPA, DOE doesn't have the contracting power to require private companies and utilities to use the technologies that an ARPA–E might produce. We are still not sure how best to clear the hurdle from basic, applied research in our National Labs, to applying that research in the commercial market. It is reasonable to think that without the ability to mandate applications, the higher risk ARPA–E programs would be able to conquer that tech transfer challenge. It is the question.

So, hopefully, these questions, the one about whether it would siphon off funds, and the one about whether the lack of contracting power will affect the success of an ARPA–E, are two questions that we can discuss here today, as well as refinements to the bill.

In any event, I think we can all agree that science and technology holds some of the solutions to the most pressing problems that we face, especially our dependence on fossil fuels from the most unstable regions of the world make us a nation at risk. We must break through to alternative sources of energy, and I hope that ARPA–E, if we create an ARPA–E, that it can be a big part of that story of success and progress.

So, thank you again for holding the hearing, and I look forward to discussing these questions, and hearing what the panel has to say about a new ARPA–E.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Good afternoon. Thank you, Mr. Chairman, for holding this hearing on the establishment of the Advanced Research Projects Agency–Energy (ARPA–E).

Mr. Chairman, we share the same vision: America serving the world and succeeding as the leading technological innovator.

We share the same goal: creating incentives for technological advancement.

We share some of the same strategies and tactics toward the attainment of the goal and the fulfillment of the vision.

I'm not opposed to creating a federal agency within the Department of Energy to mimic the risk-embracing and entrepreneurial qualities of the DARPA program. It is possible that the ARPA–E research could eventually offer a big payoff in the commercial energy market. At the same time, I already see real payoffs coming from existing DOE research, especially hydrogen, nuclear, wind, and solar programs. I'm concerned that the ARPA–E fund will divert funds away from these existing programs and jeopardize the advances we're already seeing in these areas. I hope that we can find a way to ensure that this doesn't happen.

Unlike DARPA, DOE doesn't have the "contracting power" to require private companies and utilities to use the technologies ARPA–E might produce. We're still not sure how best to clear the hurdle from basic, applied research in our national labs to applying that research in the commercial market. Is it reasonable to think that, without the ability to mandate applications, the higher risk ARPA–E programs would be able to conquer that tech transfer challenge?

Hopefully, these questions will be addressed in this hearing today and in refinements to the bill.

In any event we can all agree that science and technology hold some of the solutions to the most pressing problems we face. Our dependence on fossil fuels from the most unstable regions in the world make us a nation at risk. We must break through to alternative sources of energy, and I hope that ARPA–E can be part of that process.

Thank you again for holding this hearing, Mr. Chairman, and I look forward to discussing these questions with you and with the panel.

Chairwoman GIFFORDS. Thank you, Mr. Inglis, and if there are Members who wish to submit additional opening statements, their statements will be added to the record.

[The prepared statement of Mr. Bartlett follows:]

PREPARED STATEMENT OF REPRESENTATIVE ROSCOE G. BARTLETT

Energy is the biggest challenge facing America and the world in the 21st Century. Energy, particularly our reliance upon cheap energy and specifically, fossil fuels, is a high-stakes problem that is the foundation of concerns about peak oil, climate change, geopolitical stability, national security, and economic prosperity. These issues alone and certainly combined support the imperative to develop sustainable, renewable sources of energy as alternatives to fossil fuels. In response to this complex situation, the U.S. needs to invest in particularly high risk, high potential research.

I am a co-sponsor of Chairman Gordon's bill, H.R. 364, that seeks to do this by establishing an Advanced Research Projects Agency for Energy (ARPA–E) within the DOE. This new program would be charged with the mission of reducing U.S. dependence on oil through the rapid development and commercialization of transformational clean energy technologies.

An array of new possibilities needs to be explored with more research. Research and development is currently tremendously under-invested in this area. I understand that only one-tenth of one percent of the transportation industry's $1.8 trillion annual revenues is dedicated to R&D compared to an industry standard of five percent to 10 percent. In the past three decades, energy R&D spending has dropped by two-thirds. H.R. 364 proposes $300 million in research funding, but this would amount to less than 0.02 percent of these industries' annual revenues.

We are very much like the lucky couple with a big inheritance that provides them with 85 percent of their income. They realize that the inheritance will run out long before their retirement so they will have to earn more or spend less or a combination of both. That is about where we are with energy. Fossil fuels provide 85 percent of the energy we consume. In order to make substantial strides, we need to establish ARPA–E and invest much more in conservation, efficiency and alternative renewable sources of energy.

As the bill states, similar to the Department of Defense's successful Advanced Research Projects Agency (DARPA), the proposed organizational structure will be better positioned to support innovative and transformational energy research where risk and pay-offs are both high. Dr. William Bonvillian testified that the key to DARPA's success has been its innovative culture. Key to DARPA's success has been identifying and supporting revolutionary technology breakthroughs. DARPA has adapted to create the means for more easily crossing the "Valley of Death" between innovations in the lab and success in the marketplace.

We need more investment in addressing the "DARPA-hard problems" and enormous challenges in the transition that we have to make from fossil fuels to sustainable, renewable sources of energy. We are so far behind what needs to be done. We are 37 years past peak oil in the United States. Global peak oil is inevitable and most experts in a GAO report that I requested project it could occur anytime between now and 2020. We do not have anymore time to waste. ARPA–E would be a beginning in emulating the structure and success of DARPA by attracting talent to solve DARPA-hard energy problems. We need to have this in order to solve the energy crisis of the 21st Century.

I was one of the scientists and researchers whose imagination was captured and galvanized by President Kennedy's challenge to land a man on the Moon by the end of the decade. I worked on the Mercury, Gemini and Apollo programs. It showed me that government leadership makes a difference in working to overcome unimaginable challenges.

The father of America's nuclear navy, Admiral Hyman Rickover, said in a speech almost 50 years ago that fossil fuels are finite. Once burned, they're gone. We are about 150 years—I believe halfway—through the age of oil. Rickover describes it as a golden age. The energy from oil is incredible. We have built a civilization that is utterly dependent upon oil. However, in 5,000 years of recorded history, the oil age will be a blip.

What energy source will come next? We have an obligation to future generations to preserve prosperity. This will not happen unless we lead a transition from finite fossil fuels to sustainable, renewable sources of energy. This situation is similar to a farmer eating seed corn; we are compromising our future harvest. We are endangering our prosperity and personal obligation to our children and grandchildren and compromising their potential for a safe and prosperous world.

This energy crisis poses a threat to our national survival similar to what prompted the creation of DARPA in 1957. We should feel the same urgency as there was in 1957 and be willing to invest in our future. The creation of ARPA–E will help us to overcome this momentous challenge.

Chairwoman GIFFORDS. At this time, I would like to introduce our witnesses. I would like to start with Mr. John Denniston, who is a partner at the venture capital firm of Kleiner, Perkins, Caufield & Byers, where his portfolio includes investments in clean energy and greentech businesses, and has a particularly valuable perspective as an experienced investor in cutting edge technologies. Mr. Denniston recently met with the Governor of the State of Arizona, Janet Napolitano, so hopefully, we will have a chance to hear a little about that as well.

Our next witness is Mr. William Bonvillian, and he is the Director of the Washington Office of the Massachusetts Institute of Technology. Previously, he served as legislative director and chief counsel to Senator Lieberman, where he worked on, among other things, the establishment of a DARPA-like program at the Department of Homeland Security.

Dr. Stephen Forrest is the Vice President for Research at the University of Michigan. Dr. Forrest has held a number of positions in academia and industry, and we look forward to his discussion of the role of university and industry partnerships in energy research and development. Thank you for being here Dr. Forrest.

And our final witness is Dr. Richard Van Atta. He is a Senior Research Analyst with the Science & Technology Policy Institute of the Institute for Defense Analyses, and one of the preeminent experts on the ARPA model for technology development.

And our witnesses should know that spoken testimony, we like to try to limit it to about five minutes, but obviously, we are going to give you the time that you need, and we certainly, we have questions, and I am looking forward to a really good dialogue.

So, let us get going with Mr. Denniston.

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

Mr. DENNISTON. Good afternoon, Chair Giffords, Ranking Member Inglis, Chairman Gordon. I am John Denniston. I am a partner with the venture capital firm Kleiner Perkins Caufield & Byers, based in Silicon Valley California. I am honored to be here today.

Kleiner Perkins is a founder of TechNet, a network of technology entrepreneurs and CEOs, and a member of the National Venture Capital Association. My testimony today reflects my own views.

Together with so many other Americans, venture capital professionals are deeply concerned about the risks to our nation's welfare posed by our energy dilemmas. We see three distinct challenges, each of them urgent: the dangers resulting from climate change, our foreign oil dependency, and the risk to American competitiveness if we fail to lead the global race to develop clean energy technologies. Yet, we also have faith these challenges present new opportunities to create jobs and prosperity. Over the past seven years, at Kleiner Perkins, we have focused on a new industry, dubbed greentech, which encompasses clean power, transportation, and water. Throughout the world today, greentech progress is already shaping the newest industrial revolution. The only question is, will America once again lead the way?

I have addressed your specific questions in depth in my written testimony, and added some additional thoughts on the particulars of H.R. 364. In the interests of time this afternoon, I would like to focus my oral remarks on three issues: ARPA–E's mission, research funding levels, and some reasons for optimism that a new public-private partnership can create solutions to our energy predicaments.

My first point is ARPA–E's mission should be to fund results-oriented translational research for renewable energies, energy efficiency, and carbon capture and sequestration technologies. I do not believe Congress should include within ARPA–E's charter any other fossil fuel technologies or nuclear power. They already dominate our energy system, needing no regulatory push to achieve market acceptance. Further, the translational research process is much better suited to identifying breakthrough technologies in emerging areas, rather than introducing incremental improvements in mature ones.

Second, I will speak to energy research funding. Total federal spending on renewable energy research, the clean technologies essential for a healthy, prosperous future, amounts to little more than $1 billion per year. Frankly, this is inadequate relative to the scope of our problems, and the sheer size of the energy and transportation industries, which amount to over $1.8 trillion annually. We are way off scale. Big challenges demand commensurate responses. Our history shows how well Americans understand this.

When the Soviet aerospace lead threatened U.S. prestige, we devoted $140 billion, in current dollar terms, for the Apollo Project. When DARPA was established in 1958, to combat Soviet troop superiority with superior military technology, it received an initial budget appropriation of $500 million. That was equivalent to $3.5 billion in 2007 dollar terms, and that was more than 16 times the federal budget share devoted to renewable energy research today.

A final, more recent point of comparison. Years ago, Congress decided to prioritize finding cures to human disease and quintupled medical science research through the NIH, which today stands at $28 billion annually. During the same period, energy R&D declined by two thirds. I want to be clear. This is not to suggest that the NIH budget should be reduced. That would be a mistake. My point is, current federal renewable energy research funding, and with all due respect, the proposed funding levels under H.R. 364, are dangerously deficient. I do empathize with the difficulty of finding new appropriations in the current budget environment. We can discuss that, Chairman Gordon, afterwards, but we simply must find a way to treat our energy predicaments as a top national priority.

Finally, I would like to speak to the economic opportunity for the United States. I am very optimistic. Increased federal sponsorship of clean energy will pay off not just in terms of climate stability and national security, but also in American prosperity. In Silicon Valley, we often refer to a principle known as Moore's Law, the idea that semiconductor performance doubles every 24 months. This rule is the fundamental underpinning of the information revolution, and today, we are seeing something remarkably similar in the energy field, a rapid cost reduction curve promising exponential growth and technological solutions we can't even imagine today.

American scientists are ready to innovate our way out of our energy dilemmas, but the speed at which they do so will depend on government policy that is as bold and creative as they are. I am grateful for your leadership with this initiative today, and I am happy to be at your disposal, to help build a cleaner, more secure energy future that will allow America to lead the next industrial revolution.

[The prepared statement of Mr. Denniston follows:]

PREPARED STATEMENT OF JOHN DENNISTON

Introduction

Good morning, Chairman Lampson, Ranking Member Inglis, and Members of the Subcommittee. My name is John Denniston. I am a partner at the venture capital firm Kleiner Perkins Caufield & Byers, based in Silicon Valley California. Founded in 1972, Kleiner Perkins is one of America's oldest and most successful venture capital firms. I'm honored to be here today and to have the chance to share my views on federally-sponsored energy research.

Along with the rest of America, venture capital professionals—Republicans and Democrats alike—are deeply concerned about the risks to our nation's welfare posed by our energy dilemmas. Worried as we are, however, we are also in a unique position to recognize that each of these challenges offers new opportunities to build our economy, creating innovation, jobs and prosperity.

Our daily work at Kleiner Perkins is to recognize emerging technology and market trends. We've funded more than 500 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, Millenium Pharmaceuticals, Netscape, Sun Microsystems, Symantec, and VeriSign. Today, our portfolio companies collectively employ more than 275,000 workers, generate $90 billion in annual revenue, and contribute more than $400 billion of market capitalization to our public equity markets.

We now see a similar promise in the energy field—the potential to create jobs and new prosperity for generations to come. We refer to this emerging industry, encompassing clean power, transportation and water technologies, as "greentech."

Kleiner Perkins is a member of the National Venture Capital Association and a founding member of TechNet, a network of 200 CEOs of the Nation's leading technology companies. I serve on TechNet's Green Technologies Task Force, which last month released a detailed set of policy recommendations to drive the development and adoption of technologies we believe can help solve some of the world's most pressing energy and environmental problems. My testimony today reflects my own views.

You've asked me specifically to address energy research and development, and in particular, H.R. 364, which proposes the establishment of ARPA–E. I applaud your consideration of this critical issue. I do believe focused federal funding through a new agency, in addition to increased research funding from the Department of Energy, should be an element of America's new energy plan, and am happy to offer some suggestions as to how that might happen. In my view, we will not be able to address our energy problems unless there is a strong public-private energy partnership, one element of which must be a new commitment to federal leadership, including bold new policies and financial resources.

Before answering your questions, I'd like to first say something about the overall objectives of federal energy research. Specifically, I want to articulate what I believe are the energy dilemmas we need to resolve. Clarity of purpose will help shape our policy initiatives.

The Challenges

I believe there is an unprecedented degree of consensus in America today as to our three main energy challenges: the climate crisis, our dependence on oil, and the risk of losing our global competitive edge by failing to champion new technologies that are becoming a huge new source of economic growth, jobs and prosperity.

The Climate Crisis

In February of this year, a report of the more than 2,000 scientist members of the Intergovernmental Panel on Climate Change warned us, once again, that the planet is warming, glaciers are melting and sea levels are rising. The panel concluded, with ninety percent certainty, that human greenhouse gas emissions are fueling these dangerous trends.

The IPCC released a second report earlier this month, in which it predicted dire consequences for our increasingly unstable climate. Areas already without sufficient rain will become even drier, leading to less food production and more hunger. The world will face more serious floods and more severe storms. There's increased risk of disease.

Last week, a panel of a dozen of America's most respected retired military generals and admirals warned global warming poses a serious threat to America's national security. They urged the United States to commit to a stronger national and international role to help stabilize climate change at levels that will avoid significant disruption to global security and stability.

Many scientists predict we have only a short period of time to make dramatic cuts in our greenhouse gas emissions or risk irrevocably changing the climate. In fact, the IPCC report concludes temperatures and sea levels would continue to rise even if we were somehow able to immediately stabilize atmospheric concentrations. To date, we have failed to heed such warnings.

Energy Security

As for our energy security dilemma, this subcommittee is well aware the U.S. imports about 30 percent of its overall energy needs, including approximately 60 percent of its oil. Rapid growth in worldwide energy demand has stretched supplies, tripling the price of both crude oil and natural gas. And there is a significant risk this trend will continue, as world population and energy demand increase.

Global Competitiveness

Finally, our future prosperity is at risk, and here I speak from personal experience. In the past year, as I've traveled on business to China and Europe, I've witnessed how the rest of the world is striving, and often succeeding, to emulate the technology innovation that has been a hallmark of the U.S. economy and perhaps the single most important driver of our enviable standard of living. Increasingly, entrepreneurs overseas enjoy advantages in the form of determined government policies, including financial incentives and large investments in research and development.

Credible economic studies suggest our technology industries are responsible for roughly one-half of American GDP growth. Our country would look quite a bit different today had we not, several decades ago, become a global leader in bio-

technology, computing, the Internet, medical devices, semiconductors, software and telecommunications.

Today, as our global energy challenges become ever more pressing, it's clear future economic growth throughout the world will depend to a great degree on new technologies to help us preserve our environment. Green energy technologies could very well become the economic engine of the 21st Century. Given its potentially massive market size, "greentech" could be the most powerful economic force of our lives. But will America again lead the way?

Subcommittee Questions

I'll proceed now to your specific questions:

1. If ARPA–E is established, what technology areas should be explored?

I believe there are two dimensions to this question: what stage of energy research should ARPA–E target, and what types of energy research projects should this new agency fund?

First, I believe there's a critical need for the Federal Government to pursue translational research in the energy field. Translational research differs from basic and applied research in that it begins with the project management team members identifying the most pressing market needs. Next, they select and fund the most promising scientific approaches that might enable breakthrough products, and finally work to push the best candidates through to the brink of production. This process is also known as "right to left" research since the ends determine the means.

Translational research is by no means a substitute for basic or applied research—both of these are also critically important. But when it comes to energy issues, translational research has received only scant federal support—thus, this is where a new research agency could make the biggest difference. Translational research on defense issues at DARPA, after all, has resulted in the commercialization of many important technologies, including the precursor to the Internet, robotics, high-energy lasers, computer hardware, software and semiconductor fabrication.

To whatever degree possible, the legislation creating the new energy research agency should support a distinct culture and structure—with both, ideally, mirroring DARPA's successful traits. Like DARPA, the new agency should be small, nimble, unafraid of risk, and "flat"—i.e., non-hierarchical. It should also have cabinet-level sponsorship and support. This separate structure and identity would allow the new agency to create and sustain a culture suitable for translational research.

With respect to the energy source question, I recommend ARPA–E fund renewable energies and energy efficiency technologies, including advanced batteries, fuel cells, solar, wind, geothermal, and biofuels.

Given the urgency of reducing carbon emissions from coal-fired power plants, I believe ARPA–E should additionally have funding oversight for carbon capture and sequestration research. Other than this, however, I do not believe Congress should include fossil fuel technologies or nuclear power in ARPA–E's charter.

ARPA–E's mission should be to fund projects that can solve our urgent energy challenges: climate change, energy security and American competitiveness. And our best hope of doing so is to rapidly develop clean, alternative energy sources. Our experience with DARPA should encourage us to expect ARPA–E to identify and develop innovative and commercially viable energy technologies we have not yet even considered.

Fossil and nuclear energy sources already dominate our energy system, needing no regulatory push to achieve market adoption. Nor is the translational research process I've described above, and which I so strongly recommend for ARPA–E, designed to make incremental improvements to mature technologies such as these. On the other hand, translational research would be an excellent fit for emerging renewable energy, energy efficiency and carbon capture and sequestration technologies.

Finally, there is a question as to whether ARPA–E should also fund demonstration projects. There is no doubt the Federal Government should significantly increase its support for demonstration projects. In theory, ARPA–E could be the vehicle to do so. However, some have questioned whether this would confuse ARPA–E's mission and be contrary to the goal of creating a small, nimble organization. DARPA benefited enormously over the years from its focused mission and consistent culture. The Subcommittee should be mindful of this history as it thinks through the optimal approach to demonstration projects. One potential strategy would be to create a separate division within DOE to manage demonstration projects.

2. What value can federal resources bring to technology investors and the private sector in developing innovative energy technologies?

Federal resources can accelerate the adoption of innovative energy technologies in three ways: provide a level of research funding commensurate with the scope of our challenges; impose a price on carbon emissions that reflects their actual costs; and help create market conditions that are receptive to new energy solutions.

Accelerate Renewable Energy and Energy Efficiency Technologies by Substantially Increasing Federal Research Funds

The Federal Government should significantly increase funding for energy research and development. My understanding, based on a recent review by the American Association for the Advancement of Science, is the Federal Government currently provides roughly $1 billion annually for all non-nuclear, clean and renewable energy research. This is for our fast-changing energy and transportation industries, which account for more than $1.8 trillion of our current gross domestic product annually. Senior personnel at many of the top U.S. academic institutions have emphasized to me how little federal energy research funds are available for non-nuclear technologies—the cleanest, safest way out of our energy predicament.

In the health care sector, in contrast, the National Institutes of Health annually provide $28 billion in research funding. In the past three decades, while energy R&D spending has dropped by two-thirds, health care R&D has more than quintupled. The research-dollar discrepancy between the energy and health care fields is particularly striking when you consider that each accounts for roughly 15 percent of U.S. GDP. I want to be clear—I am not suggesting for a moment the NIH budget should be reduced. That would be a mistake. My point is we must find a way to increase federal sponsorship of clean energy research, several-fold, to build up this young industry sufficiently to give ourselves a fair chance of solving our three serious energy problems of climate change, energy security and global competitiveness.

Solving these problems will take all the leadership and financial commitment we can muster. Consider: America, in current purchasing power, spent over $20 billion on the Manhattan Project and over $135 billion on the Apollo Project. Further, 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 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.

Beyond increasing overall energy research funding, Congress should ensure the vast majority of new funding targets renewable energy and energy efficiency. Over the past 50 years, nuclear energy has received over 95 percent of U.S. funds spent on non-fossil fuel energy sources. We need to level the playing field.

Boosting our commitment to renewables today is the best investment we can make to guarantee our future economic competitiveness. I'm convinced the next global industrial revolution will depend on the substitution of renewable energy for incumbent sources. Countries that develop strong domestic greentech industries will surely advance their economies and provide the jobs of the future.

Will we be one of these leaders? After all, our standard of living today is the highest in the world, largely due to our leadership in technology innovation over the past half-century. But if we don't act decisively while we still have the time, we could easily be left behind in this new wave of innovation, eventually becoming a buyer, not a seller, of the pioneering energy technologies the world will demand.

Impose A Price On Carbon Emissions

Economists have been urging us for years to put a price on carbon that would accurately reflect its costs to society. Making fossil fuels more expensive will make newer, cleaner power sources relatively less costly, thus increasing demand for them. There are two ways to accomplish this: a carbon tax, and a carbon cap-and-trade system.

A carbon tax has the advantage of simplicity and speed of implementation, but there are two key shortcomings: taxes of any sort are politically unpopular, and we will not know for certain the reduction in carbon emissions that will result from any given level of taxation. As to the political issue, however, I would argue public sentiment has changed so dramatically in just the past couple of years, which brought us Katrina, "An Inconvenient Truth," and the last two IPCC reports, that policies once considered unacceptable may now be possible. Al Gore, when he was here, advocated an innovative "tax shift" that would achieve tax revenue neutrality by eliminating the payroll tax simultaneously with the adoption of a carbon tax. I recommend Congress explore Mr. Gore's idea.

A well-designed cap-and-trade system would address the second problem with a carbon tax: it would offer certainty in emissions reduction. An additional advantage

is that while it penalizes companies that continue to pollute, it also rewards those that make progress in adopting clean energy. America had success with a cap-and-trade system in the 1990s, when it was used to curb sulfur-dioxide emissions causing acid rain.

In my view, Congress should consider a combined carbon tax/cap-and-trade package that would offer the implementation speed of a carbon tax, along with the predictable environmental outcome of a cap-and-trade system. This combination strategy would not result in a "double tax." Instead, it would ensure we establish a carbon price level that achieves the reduction target as quickly as possible. If the carbon tax reduces carbon emissions to at least the level required by the cap-and-trade system, there simply won't be as many trades.

Create Market Conditions Supporting Renewable and Energy Efficiency Solutions

There are several measures Congress should enact to accelerate the adoption of renewable energy sources, including:

- *Renewable Portfolio Standard and Expanded Renewable Fuel Standard.* A new federal RPS, and a substantially higher RFS threshold, would send a powerful signal to the private market. Entrepreneurs and investors could be confident a market will exist for innovative new products, even if they have not yet had a chance to achieve economies of scale.
- *Federal Incentives to Drive Clean Energy Development.* Potential mechanisms include tax credits, subsidies, and loan guarantees. In addition, Congress should consider creating incentives for U.S. greentech companies to manufacture their products in this country. European and Asian countries offer incentives for U.S.-based companies to establish manufacturing operations overseas, in some cases including government payment of 40 percent of upfront capital costs and 15-year tax holidays.
- *Energy Efficiency Standards.* The United States could make great headway in solving our energy challenges by simply combating wastefulness. To this end, Congress should strengthen CAFE standards, require energy efficiency standards for electronic equipment and appliances, and work with states to create similar standards for buildings. Congress should also evaluate how to work with utilities so their profit potential is driven as much by introducing energy efficiency as it is by selling power.
- *Federal Procurement.* The Federal Government is the single largest U.S. energy consumer. As such, it can lead our energy transition by becoming the single largest green-technology user.
- *Biofuels.* Congress could take several steps to strengthen the rapidly emerging biofuels market. One of these should be an increase in the Renewable Fuels Standard consistent with President Bush's call to reduce gasoline consumption by 20 percent over the next ten years. Another contribution would be to restructure the existing blender's credit so it is paid to ethanol producers rather than gasoline distributors, provides a credit level that is inversely related to the price of gasoline (creating a safety net for ethanol producers in the case of a sudden drop in gasoline prices), and is made available to all alternative fuels, not just ethanol and specific molecular formulations of butanol.

3. Can you comment on the relationship between the federal, university and private industry sectors in energy research and technology development? Would an ARPA–E enhance this relationship to get more technologies into the marketplace?

Historically, the Federal Government, American research universities and private industry have collaborated to unleash innovation in the information technology and life science sectors. The Federal Government's indispensable role has been to fund basic and applied research, and in some cases, translational research.

I will share two examples. In the 1960's and 1970's, NIH funding for basic research in genetics at many U.S. universities helped launch what is today's flourishing biotechnology industry. Similarly, in the 1970's and 1980's, DARPA provided funding to U.S. universities to first research, and later create, a communications network to tie together the Department of Defense and the various groups around the country performing defense research. That network, known as DARPANET, was the precursor to the Internet. The Federal Government's funding role has had a mighty impact: without it, U.S. biotechnology and Internet industries would surely not be as advanced as they are today.

Today, however, with only a few exceptions, such as nuclear technology, the DOE provides very little energy research funding to American universities. As a result, there is very little government-university-industry collaboration in the alternative energy world. In fact, today's state of affairs may be discouraging American scientific talent from entering this important sector. Many senior university researchers have told me scientific talent would immediately flow into the renewable energy field if only federal research dollars were available to support projects.

Congress now has a chance to revive the productive partnership of the past. It can create a new agency to pursue translational research focused on renewable energy, energy efficiency, and carbon capture and sequestration projects. It can also demonstrate its commitment to solving our urgent energy predicaments by significantly boosting overall renewable energy funding—both within DOE and in this new agency—to a level commensurate with the scope of the challenge.

4. Is there a concern in the business and financial communities about commercializing technologies developed by the Department of Energy? If so, what steps should be taken to ensure that the technologies developed within ARPA–E will make a comfortable transition to commercial application?

The only concern of which I am aware is there have historically been few opportunities to commercialize breakthrough energy technologies sponsored by the Department of Energy outside of the nuclear field. I can assure you private industry will be eager to do its part if the volume of DOE-sponsored renewable projects increases.

As for the second part of this question, I'll repeat what I've said above. ARPA–E can play a vital role in ensuring technologies cross the divide from laboratory to market by introducing a translational research approach to federal research funding, focused on renewable energy, energy efficiency, and carbon capture and sequestration.

Additional Comments on H.R. 364

I'd like now to offer my thoughts on a few specific provisions of H.R. 364.

Goal

The expressed goal of H.R. 364 is to "reduce the amount of energy the United States imports from foreign sources by 20 percent over the next 10 years." There is a great advantage to having this kind of clarity, but I urge you to expand your objectives. While our reliance on foreign oil is a serious issue, it's just one part of our energy predicament. I do believe we must also keep in mind the serious problems looming for our nation if we don't act boldly to solve climate change and reestablish our technological leadership by leading the new green industrial revolution.

Furthermore, I see that part of the goal of the bill is to accelerate innovation in "both traditional and alternative energy sources. . ." As I have explained above, I strongly suggest ARPA–E's mandate focus on renewable energies, efficiency strategies and carbon capture and sequestration techniques.

Structure

H.R. 364 proposes placing ARPA–E within the Department of Energy. Others have suggested the agency might have more success if established as a quasi-independent agency outside of DOE. I'm not an expert in this area, but would urge Congress to adopt the organizational structure that would give the new agency maximum autonomy so it can foster a nimble, fast-moving, risk-taking culture, and at the same time, provide it with cabinet-level protection and support to keep it adequately funded and effective.

Funding

H.R. 364's proposal to create a fund which will receive $300 million in appropriations in 2007 and scale up to $915 million in 2012 is far short of what is required to solve our energy problems. I refer you to my answer to Question 2, above. While I do appreciate the difficulty of finding resources for new projects, we need to bear in mind the massive scale of the American energy and transportation industries, which account for more than $1.8 trillion in combined annual revenue, amounting to roughly 15 percent of U.S. GDP. The proposed $300 million in research funding would amount to less than 0.02 percent of these industries' annual revenues. We need to do much more, and move much faster, if we're to have any chance of solving our problems while we still can. We can and must do better than that.

Recoupment

Frankly, I believe the recoupment provision in H.R. 364 is inappropriate for translational research funding projects. It appears, moreover, to be a departure from past practices, with many unanswered questions about how it would work. Would an ARPA–E aim to recoup its investment from our research universities? From industry partners? The provision will likely deter some potential industry collaborators and almost certainly slow down the commercialization process. Let's not attach a string to these funds. If ARPA–E succeeds in commercializing breakthrough technologies, the Federal Government will be compensated many times over in the form of income and payroll tax revenues.

Review

H.R. 364 calls for the President's Council of Advisors on Science and Technology to evaluate ARPA–E just two and a half years after it is established, to determine whether it should be discontinued. To me, this seems counterproductive. If ARPA–E isn't working as well as it should, let's fix it. Let's not structure this new agency so that all translational research for renewable energy, energy efficiency and carbon capture and sequestration might cease because the agency fails to produce results in short order. Setting an unrealistic timeline would surely also make it difficult to hire top-flight talent.

Reason For Hope: The Opportunities

I would like to conclude my remarks by saying how confident I am we can solve our energy challenges through a new public-private partnership.

Kleiner Perkins has been investing in greentech for the past seven years, backing more than 15 innovative companies in the fields of biofuels, coal gasification, energy efficiency, energy storage, fuel cells, solar energy, thermoelectrics and transportation. In the process, we've witnessed how technological progress is already revolutionizing our relationship with energy, solving problems that only recently seemed all but intractable. Solar manufacturers are innovating their way around silicon shortages, with next-generation materials including pioneering thin-film technologies. The agriculture industry is producing transportation fuels from plant matter—even from microscopic algae—and is developing exciting new way to convert weeds to biofuels. Nanotechnology breakthroughs are creating the promise of new ways to store energy, which in turn could dramatically speed up market adoption of solar and wind power.

At Kleiner Perkins, four accelerating trends have encouraged us to make greentech a core investment sector:

- We're already seeing exponential growth in the energy technology field, with a rapid cost-reduction curve sure to become ever steeper over time, making emerging sources of energy increasingly competitive;
- Rising prices for fossil fuels—oil and natural gas—are making competing alternative energy sources more attractive;
- World-class talent, with both missionary and monetary motives, is racing into the greentech sector;
- Americans are growing much more aware of and concerned by our energy crises, a development we believe will lend support to more sweeping policy solutions.

Moore's Law & The Pace of Technological Progress

In Silicon Valley, we often refer to a principle known as Moore's Law, which I'd like to explain briefly here, as it's fortunately quite relevant to what we see happening in the energy field. Intel co-founder Gordon Moore has been credited with predicting, back in the 1960s, that semiconductor performance would double every 24 months. That prediction was spot on, and helps explain the information technology revolution of the past three decades. Better, faster, and cheaper silicon chips led our transition from an era—remember, it was just 25 years ago!—of big, mainframe computers used principally by university researchers, to our capacity today to read the morning's headlines on our cell phones.

Today, we can already see a Moore's Law dynamic operating in the energy sector, giving us confidence the rate of greentech performance improvement and cost reduction will offer new energy solutions we can't even imagine right now. At Kleiner Perkins, we are excited by the technical breakthroughs we have seen in a host of scientific disciplines relating to the energy sectors, including material science, physics, electrical engineering, synthetic chemistry, and even biotechnology. We are particularly encouraged by innovations resulting from a combination of breakthroughs in several of these separate disciplines into single products.

Witness some of these examples of the greentech equivalent of Moore's Law:

- The price of wind power has plummeted by an order of magnitude since 1980, to the point where, in some regions, it is now very close to being able to compete with coal and gas power;
- Solar power costs have fallen by more than 60 percent over the past fifteen years;
- Ethanol production efficiencies per gallon have improved by more than 45 percent since 1982.

These and other improvements have occurred over a period of time in which there was relatively little government policy or entrepreneurial focus on these sectors.

Today, the high cost of many new energy sources, relative to the incumbent competition, represents the most serious barrier to greater capital investment and more rapid adoption of clean power. Why does green power cost more? Primarily because it's so new. Being new, it is still at the very early stages of its cost-reduction curve, and is being produced in such low volumes that the industry has yet to benefit from economies of scale.

We can be certain American scientists and engineers will continually innovate to improve the performance and reduce the costs of these technologies going forward. But the speed at which they do so will depend to a large degree on government policy that is as bold and innovative as they are. With strong Federal Government leadership, imagine what American ingenuity will be able to accomplish in the future as more and more of our best and brightest devote their life's work to the greentech field.

Once again, I want to thank the Subcommittee for inviting me here today. I believe we all have an opportunity to be part of the solution to our country's energy crises. I look forward to today's hearing and to learning about how we can work together to build a more secure future.

BIOGRAPHY FOR JOHN DENNISTON

John Denniston came to KPCB from Salomon Smith Barney, where he was a Managing Director and head of Technology Investment Banking for the Western U.S., and also served on the Investment Committee for Salomon's direct investment venture fund and its venture capital fund-of-funds. Prior to Salomon, John was a Partner with the law firm Brobeck, Phleger & Harrison, where he was the head of Brobeck's Venture Capital Practice Group, Co-head of its Information Technology Practice Group and a member of the Investment Committee for its venture capital fund.

Chairwoman GIFFORDS. Thank you, Mr. Denniston. Next, we are going to hear from Mr. Bonvillian.

STATEMENT OF MR. WILLIAM B. BONVILLIAN, DIRECTOR, WASHINGTON OFFICE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. BONVILLIAN. Thank you, Madam Chairman, Ranking Member Inglis, Chairman Gordon, Members of the Subcommittee. I appreciate the opportunity to talk with you today. I want to note at the outset that the views I am going to express are not necessarily those of my employer, MIT.

Let me first discuss the energy technology challenge. John has summarized that this is a high stakes challenge. Some have called for a Manhattan Project, some have called for an Apollo Project. Those famous technology development projects were focused on single technologies to be stood up in a comparatively short period of time, with a single customer with very deep pockets, the government. They were not designed for deeply embedded, stratified, highly competitive private sector markets. We are going to need an array of new technologies launched over a period of time, and there is going to be no short-term single energy silver bullet.

You know, getting to the Moon in some ways starts to look fairly simple, given the complexities of the task that we have in front of us. Do we have the right institutional models that are going to put us in a place to handle this kind of challenge? And I would argue that the translational model is potentially an applicable model for this energy innovation challenge. Over the last half century, the big problem that we have had in launching new technologies has been to bridge the valley of death between the research side and the innovation side.

The most successful model, as the Subcommittee well knows, has been DARPA, established by President Eisenhower in '57. It is sort of a model that works right to left, it looks at the right side of the innovation pipeline, the kind of results that may be needed, and then reaches back to the left side to figure out the fundamental science breakthroughs that are going to get us to the responses that we need to have on the right side. To borrow a phrase from MIT's President Susan Hockfield, it is very important that science sow lots of fields of wildflowers, but in addition to that, it is very important to bring those wildflowers into a garden occasionally, and gardening has been DARPA's business.

Erich Bloch, who was President Reagan's very noted head of NSF, pointed out, research that collects dust on a shelf is not worth much to society. DARPA has attempted, not always successfully, but attempted to move things off the shelf. Let me emphasize, too, that an ARPA–E is not going to be able to impose technology solutions on the private sector. Its role is going to be to expand those options, to reduce the technology standup barriers and risks, to make them within range of private sector acceptance. This is going to have to be a collaborative effort.

Let me dig a little deeper into the DARPA culture, because I think there are some lessons here, if we are going to have an institution that is workable. First, DARPA has used something called a hybrid model. It creates collaborative teams with the best university researchers, and connects them with outstanding firms, often small or mid-sized startup firms.

These teams have created the connectedness that has enabled better movement across the valley of death that I talked about before. Now, you can't legislate culture. But you probably can put some management guidance into this legislation, and there are parts of the DARPA ruleset that I think will be critical to making the culture of this translational model work. I will just cite a few.

Keep it small, keep it flexible. Make it flat, non-hierarchical. Allow the entity autonomy and freedom from bureaucratic impediments. Get a world-class technical staff. Create outstanding teams and networks among the researcher teams. Ensure in hiring both staff continuity and change. Put the leadership in the hands of outstanding program managers. Emphasize acceptance of failure and willingness to take risks. Set an orientation to revolutionary breakthroughs. And create a mix of connected collaborators that represent a series of disciplines that come to bear on problems.

Now, in my written testimony, I have a description of some other organizational models, which the Committee asked me to talk about. Those are complex and complicated, and I have only a limited amount of time. Hopefully, we can come back to those, particu-

larly the sort of government corporation model and the experience at HSARPA, because I think there are lessons here, but let me emphasize, I think, some of what John was talking about.

We need to operate at scale here if we are going to stand this up. The energy sector is a trillion dollar sector. A modestly funded R&D effort is just not going to drive transformational shifts, and we are not to get there on the cheap. So, the funding at the outset is the critical issue. Recoupment only solves a later end problem. I agree we can talk about some of the alternative revenue sources that might be possibilities.

Let me try and summarize a few key points here. Energy technology is a major, complex challenge, probably the most difficult technology challenge we have ever faced. There is a gap in our federal innovation institutions for energy, and we will call that a translational research gap. A way of filling that gap is to follow the DARPA-like model with an ARPA–E, build it around a translational model that combines, in a hybrid approach, great university, and great firm researchers, and make them compete. The culture of DARPA is going to determine its success, not the legislative framework, so getting that culture right is crucial.

DARPA could be stood up inside DOE, it could be stood up outside it. In either case, it is probably going to have to follow what is known as an "island bridge" model. You want to allow this entity a substantial amount of autonomy to be creative, but it has to be connected back by a bridge to leaders that are going to encourage it and protect it. And you must ensure that it has support and funding. So, you need the island and the bridge.

Energy R&D is underfunded, and ARPA–E is going to need to operate at significant scale to achieve success. We should not do ARPA–E unless we are prepared to meet that challenge. An ARPA–E is not going to focus on short-term problems. We have a long-term focus that we need to tackle here.

Thank you.

[The prepared statement of Mr. Bonvillian follows:]

PREPARED STATEMENT OF WILLIAM B. BONVILLIAN

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

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

THE ENERGY TECHNOLOGY CHALLENGE:

Energy is a high-stakes problem with much hanging in the balance—energy security and resource dependency on the Middle East, climate change, economy-wide shake-downs from high cartel-imposed prices, disruptive trade imbalances, and macroeconomic trade costs.[1] In response, some have called for a Manhattan Project for new energy technology, or for the equivalent of the Apollo Moon Mission. But those famous technology development projects were focused on single technologies to be stood up in comparatively short-term multi-year projects. They were simple compared to the energy technology challenge. The technologies launched then were for a single customer with the deepest pockets, for the government sector, not for deeply imbedded, stratified and highly competitive private sector markets. Energy chal-

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

lenges require a very different development model in which a complex mix of energy technologies must evolve over decades into the private sector. As some have noted, there will be no short-term energy silver bullet.

An array of new energy technology is needed. Some of these technologies have been tested at economic scale and are ready for demonstration and implementation, others require breakthrough research, still others both breakthroughs and large-scale development. These technologies show that a new energy economy is possible if we have the political will to make it happen. A key point is that we will need many strands of technology development in multiple time dimensions; there cannot be a single technology focus. And the technology development system we create will need to consider and retain room for evolving advances over time—there will be next generation batteries and solar but there will be third and fourth generation advances that will displace the first and second generations, so there must be space for promoting both incremental advance and disruptive new technologies; technology arterial sclerosis must be avoided. We have a complex systems problem—there will be multiple energy technology pathways that must evolve over time, and each path will be different, although many will have to be complementary. This is perhaps the most complex technology evolution problem the U.S. has ever faced. It makes getting to the Moon start to look simple by comparison.

THE TRANSLATIONAL MODEL FOR ENERGY TECHNOLOGY INNOVATION:

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

The most successful model, as the Subcommittee is aware, for bridging the gap between research and innovation, for moving from the front end close to back end, in the U.S. innovation system has been the Defense Advanced Research Projects Agency (DARPA), established by President Eisenhower in 1957. While DARPA has played many roles over many years, its most important role is sometimes described as working "right-left." DARPA represented a change from the "basic science only" model of most U.S. R&D agencies and aimed for a "connected" model that bridges the "Valley of Death," reaching between research and late stage technology development up to the prototyping stage. In other words, DARPA has connected the stages in the U.S. R&D pipeline that traditionally have been institutionally separated and has put R&D and technology on a continuum. It has done this by following the "right-left" model—deciding up front on a breakthrough technology that must be achieved on the right side of the innovation pipeline, then reaching back to the left side of the pipeline to seek the most promising breakthroughs in science that must be found and nurtured to get there. This is the opposite of the curiosity-driven-research-without-regard-to-technology-objective that dominated the ethos of most U.S. fundamental science agencies. To borrow a phrase from MIT's President Susan Hockfield, for science success it is important to sow fields of wildflowers; sometimes it is also important to bring those wildflowers into a garden.

A good term for DARPA's role is *"translational"*—translating science breakthroughs into technology that gets stood up and implemented. As Erich Bloch, President Reagan's famed NSF Director, once pointed out, research that collects dust on a shelf is not worth much to our society. DARPA's role has been in nurturing technology to make sure it gets off the shelf. A DARPA-like translational "connected science" technology development role is not currently performed at DOE; there is an institutional gap there. Given the need for breakthrough energy technologies and transitioning them—and this is truly the grand technology challenge of our time—this is arguably an institutional gap that should be considered. This would be the central mission of an ARPA–E.

Let me emphasize that an ARPA–E cannot impose technology solutions on the private sector. Its role will be to expand the options, and reduce the technology stand-up barriers and risks, for private sector firms. It will need to work with the private sector to evaluate what the energy technology leverage points are, what technology paths could have maximum impact, and collaboratively explore and nurture technology opportunities.

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

The key to DARPA's success has been its innovative culture. A DARPA clone will not work unless it is able to build a strong innovation culture. DARPA provides

some important lessons. A key has been its creation of "hybrid" collaborative teams, combining the best university researchers on the research side with outstanding firms (usually startups, small or mid-sized firms hungry for technology advance) on the development side. This university-industry hybrid approach has proven a key mechanism for DARPA's success particularly on revolutionary technology breakthroughs—these teams create the capability for more readily crossing the "Valley of Death." DARPA also competes its research, looking for and regularly obtaining the country's most talented research teams. An ARPA–E must find new entrants and talent to supplement the existing research base working on energy R&D if we are to have the breakthroughs we need; a competitive hybrid model is a way to achieve this.

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

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

- *Keep it small and flexible:* DARPA consists of only 100–150 professionals; some have referred to DARPA as "100 geniuses connected by a travel agent."
- C*reate a flat non-hierarchical organization.*
- *Allow the entity autonomy and freedom from bureaucratic impediments:* DARPA operates outside the complex and slow government hiring process and standard government contracting rules, which gives it unusual access to talent, plus speed and flexibility in organizing R&D efforts.
- *Hire an eclectic, world-class technical staff.*
- *Create outstanding teams and networks among its researchers.*
- *Ensure in hiring both continuity and change:* DARPA's technical staff are hired or assigned for 3–5 years. Like any strong organization, DARPA mixes experience and change. It retains a base of experienced experts that know their way around DOD, but rotates most of its staff from the outside to ensure fresh thinking and perspectives.
- *Place leadership in the hands of outstanding program managers:* In DARPA's words, "The best DARPA Program Managers have always been freewheeling zealots in pursuit of their goals." The DARPA director's most important job historically has been to recruit highly talented program managers and then empower their creativity to put together great teams around great advances.
- *Emphasize acceptance of failure and willingness to take risk.*
- *Set an orientation to revolutionary breakthroughs in a connected approach:* DARPA historically has focused not on incremental but radical innovation. It emphasizes high-risk investment, moves from fundamental technological advances to prototyping, and then hands off the production stage.
- *Create a mix of connected collaborators from a range of disciplines.*

OTHER ORGANIZATIONAL MODELS:

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

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

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

leadership. If a government corporation model is selected for ARPA–E, a connection to the government leadership could be attempted by naming the Secretary of Energy as chairman of its board with government control of the board.

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

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

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

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

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

mixing the two risks having the former become the bill-payer for the latter. The HSARPA implementation problems also underscore the need for ongoing Committee oversight over any implementation of an ARPA–E.

THE NEED TO OPERATE AT SCALE:

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

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

If an effective macro-pricing system for carbon, such as a cap and trade program, is adopted by the U.S. because of climate change concerns, this program could, depending on how structured, generate revenues of up to many billions each year, as a carbon permitting system is put in place. Although this macro-pricing step is still likely some years away, when adopted it will not work unless there is a strong innovation system foundation placed under it. Much of these new revenues will be needed for R&D and to leverage large scale industry transition to non-CO_2 emitting energy systems. It is important that innovation system reforms be adopted now if these future resources are to efficiently and soundly invested in new technologies. ARPA–E is potentially part of that innovation institution story.

SUMMARY OF KEY POINTS:

1) Standing up new energy technologies is a major and complex challenge, perhaps the most difficult technology stand-up challenge we have faced. Ever.
2) There is a gap in the federal innovation institutions for energy around translational research. There is a need for new institutional arrangements to evolve and transition new breakthrough technologies. An ARPA–E modeled on DARPA could help fill that gap.
3) If an ARPA–E entity is formed its performance will require high performance from outstanding new research entrants, following the DARPA hybrid model of outstanding university and firm researchers.
4) The culture of ARPA–E will determine its success; authorizing legislation should include management guidelines following key points in the DARPA ruleset that have created an effective culture there.
5) ARPA–E could be stood up either inside DOE or outside it, through a federally owned corporation. In either case it will need to follow an island-bridge model, performing R&D on an island creative autonomy but tied to the most senior DOE leadership who can assist on research and political support.
6) Energy R&D is underfunded based on the technology needs we now see; we need to expand the federal R&D portfolio in energy. An ARPA–E will need to operate at large scale to achieve success in helping to transform our energy technology menu.
7) An ARPA–E should not be stood up unless R&D funding is available adequate to the significant size of the energy technology development task. The Committee should seek assurance for Appropriations funding and Executive Branch policy support if this program is to work well.
8) New energy technology will not be a short-term project. The program should maintain a long-term focus.

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

BIOGRAPHY FOR WILLIAM B. BONVILLIAN

William B. Bonvillian, since January 2006, has been Director of the Massachusetts Institute of Technology's Washington, D.C. Office. Prior to that position, he served for seventeen years as Legislative Director and Chief Counsel to U.S. Senator Joseph Lieberman. He has also taught in the area of science, technology and innovation policy.

Prior to his work on Capitol Hill, he was a partner at a large national law firm. Early in his career, he served as the Deputy Assistant Secretary and Director of Congressional Affairs at the U.S. Department of Transportation, working on major transportation deregulation legislation. His recent articles include, "Power Play—The DARPA Model and U.S. Energy Policy" in *American Interest,* "Meeting the New Challenge to U.S. Economic Competitiveness" and "Organizing Science and Technology for Homeland Security," both published in *Issues in Science and Technology,* and "Science at a Crossroads," published in *Technology in Society* and reprinted in the *FASEB Journal.* At MIT, he works to support MIT's strong and historic relations with federal R&D agencies, and its role on national science policy. His legislative efforts at Senator Lieberman's office included science and technology policies and innovation issues. He worked extensively on legislation creating the Department of Homeland Security, and more recently on Intelligence Reform and national competitiveness legislation.

He received a B.A. from Columbia University with honors, an M.A.R. from Yale Divinity School in religion; and a J.D. from Columbia Law School, where he also served on the Board of Editors of the *Columbia Law Review.* Following law school, he served as a law clerk to a Federal Judge in New York. He is a member of the Connecticut Bar, the District of Columbia Bar and the U.S. Supreme Court Bar and serves on the Board on Science Education of the National Academies of Sciences. He has lectured and given speeches before numerous audiences on science and technology issues, and has taught previously in this area at Georgetown, MIT and George Washington.

Chairwoman GIFFORDS. Thank you, Mr. Bonvillian. Dr. Forrest, please. Dr. Forrest, excuse me, could you push your button?

STATEMENT OF DR. STEPHEN R. FORREST, VICE PRESIDENT FOR RESEARCH, UNIVERSITY OF MICHIGAN

Dr. FORREST. Oh, there we are. Thank you, Madam Chairman Giffords and Ranking Member Inglis for this invitation to testify.

Few challenges are more important today than curbing the unsustainable threat to our fossil fuels dependent energy infrastructure. To meet this challenge, which extends also to the threat to our environment, almost all agree that a bold and broad approach is needed.

Renewable, inexpensive, and carbon-free energy solutions must be found. My own research in solar power and solid-state lighting has made me confident that many economically environmentally sound solutions do exist. It has been proposed here that a crucial tool for meeting these challenges is the establishment of ARPA–E, a flexible and independent agency at DOE to sponsor R&D to address the grand challenges that now face the energy sector, but in structuring such an agency, we must take care to achieve the goals of independence from carbon-emitting and foreign fuel dominated supply of fossil fuels.

My personal experience, and that of many of my university colleagues around the Nation, suggests that a successful model, as you heard twice before today, would be based on DARPA, which is highly mission-oriented, and nurtures long-term, innovative R&D investments, in ways that no other governmental agency has been so successful in accomplishing. DARPA has proven to be a critical bridge between universities and industry who can provide the technological solutions to the needs of the Department of Defense.

While DOD is its client, DARPA research has inevitably led to many commercial successes, of which most of us are well aware, for example, the Internet, cellular telephony, et cetera. Like DARPA, ARPA–E should position itself to identify the largest challenges facing our energy future. How can our energy future be cut loose from its dependence on the caprices of marginally stable foreign countries, and how can it create a portfolio of energies that reduce carbon emissions that are proving so destructive to our planet?

To accomplish this task, like DARPA, which was created to counter the Soviet threat, ARPA–E must have autonomy and freedom from bureaucratic impediments. Its mission must be to fund collaborations to develop new technological advances, and to solve a wide range of immense and common problems. This entrepreneurial model for project identification will inevitably lead to a generation of robust private industry that provides us with energy alternatives, while strengthening our domestic markets.

In this context, universities stand to play a key role as incubators for highly innovative ideas that the private sector often cannot afford to undertake. ARPA–E can assume the role of connecting universities with companies that, with their more practical perspectives, could bring the most innovative ideas rapidly into the marketplace. I would point out that DOE's current research portfolio, managed by the Office of Science, is critical to advancing innovation within the energy sector. Indeed, DOE provides two thirds of federal investment in the physical sciences, and supports thousands of researchers in fields such as computer science, engineering, and material science. However, today's energy predicament needs a new perspective.

Primarily, DOE's research structure is almost completely focused on funding the many superb National Labs. While the Labs are vital in areas such as nuclear weapons development, fundamental physics, and material studies, these large scale facilities are not organized to conduct high risk transformational research whose function is primarily in changing the energy status quo in an agile and unbureaucratic manner.

Furthermore, programs in which universities and National Labs are both allowed to compete are often dominated by the immediate need to fully support operation of the Labs. As a result, universities and the private sector are often inadequately resourced to effectively contribute to solving larger problems, thus discouraging the novel ideas that naturally emerge from their research.

Returning to the DOD model, DARPA rapidly brings innovation to the military community at comparatively low cost by focusing almost entirely on universities and the private sector. For example, over the last ten years, less than five percent of DARPA's budget has gone to DOD labs, the remainder being split about two to one for industry and academia. To achieve the same success, ARPA–E must follow a similar model. Its focus must be on moving innovations from universities into industry, and then from industry into the marketplace.

The Labs' institutional knowledge, however, should and can play a constructive role, by helping ARPA–E define the very challenges that need to be addressed, then subcontract these projects to the most innovative and cost-effective bidders. The depth of knowledge

in the National Labs has long played this role of guiding energy research. As advisor to ARPA–E, it will continue to deepen and strengthen to our nation's immense profit.

To accomplish its mission, ARPA–E cannot be subordinate to other DOE entities. The Agency's director should report directly to the Secretary of Energy, again following the highly successful DARPA model, where the Director reports to the Secretary of Defense. Also, a cap on personnel and short terms of service would keep ARPA–E dynamic, and would ensure a continual infusion of new ideas.

Obviously, adequate funding is essential. In tough budgetary times, this will be hard to come by, but changing our energy dependencies is critical, not only to our national security, but also to our economy and our global competitiveness, hence the time to act decisively is upon us. In addition to Congress providing appropriations that would not be found by taxing existing DOE agencies and labs, independent revenue streams should be considered.

Thank you again for this opportunity to testify. I look forward to contributing further in this debate.

[The prepared statement of Dr. Forrest follows:]

PREPARED STATEMENT OF STEPHEN R. FORREST

Introduction

Chairman Lampson, Ranking Member Inglis and Members of the Subcommittee, thank you for the invitation to testify today. It is my great pleasure to contribute to the ongoing debate over the establishment of a new energy research agency at the Department of Energy (DOE) to fill an unmet need: the nimble transfer of revolutionary energy research results out to the commercial marketplace. I know Congress first started working on this issue last year and I would like to take this opportunity to commend you for your leadership in the campaign to find new ways to address American's energy crisis.

As you may know, I joined the University of Michigan in January 2006 as its Vice President for Research. Prior to moving to Ann Arbor, I held several positions in academia and in industry. Over the years I have worked at places ranging from Bell Labs to USC and Princeton. I have more than 150 U.S. patents and have published over 400 papers in scientific journals, many of them in the field of energy generation and use, and have co-founded several successful companies, including Sensors Unlimited, Epitaxx, Inc., Global Photonic Energy Corp., Universal Display Corporation, and Apogee Photonics.

It is an honor to be part of higher education, but with that honor also comes responsibilities. Universities must contribute their wealth of intellectual depth and productivity to help the Nation survive what will be a disruptive and long-term transition in its energy use away from traditional fossil fuel sources. Thus, one of first acts of the university after I joined as Vice President for Research has been to initiate a unique research institute called the Michigan Memorial Phoenix Energy Institute. It is named after our Physics Memorial Laboratory, home of the Ford Nuclear Reactor that was founded by the Atoms for Peace Program started in the 1950s. The name of the institute historically honors University of Michigan alumni, students and faculty who gave their lives in World War II. The new Energy Institute's goal is to convene world experts in energy, science and technology to explore how to best find alternatives to fossil fuel to meet the growing the energy needs of our nation. Unlike other university-based energy research centers, our institute combines science, engineering, economics and public policy expertise to address the challenges facing us. Its interdisciplinary culture is essential simply because, as the Subcommittee knows all too well, the pathway to successful implementation of technological solutions in our communities is guided by public policy decisions, economics and societal change.

Our Nation's Energy Crisis

There are few contemporary challenges facing the Nation—and the world—more threatening than the unsustainable nature of our current energy infrastructure. Our

communities are dependent upon the continuing availability of clean, affordable and flexible energy resources.

Yet, our current fossil fuels-dependent energy infrastructure is unsustainable. This is a problem with potentially catastrophic consequences. Global oil production is expected to peak within the next several decades, with natural gas production peaking soon thereafter. While there are substantial reserves of coal and tar sands, the mining, processing and burning of these fossil fuels poses increasingly unacceptable biological and environmental risks, particularly within the context of global climate change. Furthermore, the security of our nation is threatened by our reliance on foreign energy imports from unstable regions of the world.

At this critical juncture, a bold and broad approach is needed to radically transform how the United States meets its energy needs. Inexpensive and carbon-free energy solutions that are renewable must be found—and I am confident that they are out there.

To just put things into context, in 20 minutes enough energy to power the earth to meet mankind's demand for a solid year is provided by the sun. If you want to think of it another way, if we constructed six solar cell fields 120 miles on a side and placed them in the temperate zones of the Earth, we would more than exceed today's demand for electrical energy. The problem with solar, and other forms of renewable energy, is that they still are not cost-competitive with that supplied by fossil fuels purchased on the world's markets.

To uncover practical applications of new ideas such as solar energy, we must harness the brain power of scientists and entrepreneurs across the country. The problems confronting mankind through the use of energy are far greater than any one institution, or one sector of our scientific and industrial infrastructure can solve. This is not a time to go it alone.

ARPA–E: Essential to Meeting the Grand Challenge

I strongly support the National Academies recommendation made in its 2005 report, *Rising Above the Gathering Storm:* create an Advanced Research Projects Agency for Energy, or ARPA–E—a small flexible and independent federal agency that "would be charged with sponsoring research and development programs to meet the Nation's long-term energy challenges."[1] According to the report, the new agency "would support creative 'out-of-the-box' transformational generic energy research."[2]

ARPA–E would be modeled on the Pentagon's successful Defense Advanced Research Projects Agency (DARPA). Created in response to the Soviet technological threat, DARPA became a critical bridge between the defense needs of the time and experts at universities and private corporations who could provide the answers.[3] While its main client has been the Department of Defense, DARPA also has supported the collaborative development of defense-based technologies for the commercial sector. Over the course of its history, it has nurtured long-term innovative research and development investments in a way that private industry could not always afford to. Through DARPA's financial awards came ground-breaking technological advances such as the Internet, GaAs technology that is now the backbone of cell phones, and wavelength division multiplexed high volume optical communications.

Today, the United States faces an even bigger and more tangible threat to our environment, our economic and intellectual competitiveness, and our national security. A new independent research agency at DOE would bring together the best minds from around the country to guide us in developing solutions for the future. It would have the autonomy and freedom from bureaucratic impediments to encourage flexibility and collaboration to solve immense and common problems facing the energy sector. Ultimately, funding from this new agency would lead to the generation of a robust private industry that would provide solutions while strengthening our domestic markets.

Universities also stand to play a key role in achieving the ARPA–E agenda. The academic environment is one in which professors are rewarded for work that their peers believe makes significant contributions to the existing foundation of knowledge. For this reason, universities have traditionally been incubators for out-of-the-box ideas that the private sector by itself often cannot afford to undertake because the risks may outweigh potential payoffs. Today, universities are looking for solutions to the energy independence challenge from all vantage points—hydrogen re-

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[1] The National Academies, *Rising Above the Gathering Storm: Executive Summary,* Washington, DC (2005), page 7.

[2] Ibid.

[3] William Bonvillian, Power Play: the DARPA Model and U.S. Energy Policy, *The American Interest,* Washington, DC (November/December 2006), p. 44.

search, improved lighting sources, biofuels, energy storage, urban planning, semiconductors, alternative fuel cars, and solar cells to name a few.

An agile, mission-oriented ARPA–E would, like DARPA, connect universities with large and small industry hungry for new advances in technology. With their more practical perspectives, the companies can take the universities' advances through to commercialization. With ARPA–E as abridge between the two worlds, the best ideas would rapidly emerge to find their place in the commercial marketplace.

Furthermore, ARPA–E sponsorship of university research would contribute to the training of the workforce—helping to ensure a steady stream of future scientists, engineers and entrepreneurs who would continue to bring talent and innovation to solving the energy crisis in years to come. As America fights to maintain its competitive edge in the world, this next generation of experts will become increasingly important.

DOE Research: Flexibility and Agility Needed

I would like to take a moment to talk about the division of research at DOE. As you know, DOE does play a critical role in advancing U.S. scientific interests. Today, it is the leading source of federal funds and resources for research in the physical sciences—providing two-thirds of the federal investment in this area.[4] In high energy and nuclear physics, nuclear medicine, heavy element chemistry, plasma physics, and magnetic fusion, DOE is the primary government sponsor. It also ranks high in overall federal support for research in computer science and engineering and sponsors significant research in biology and environmental sciences.

DOE's programs and facilities have promoted the work of thousands of researchers and played vital roles in many significant discoveries. However, to face today's energy predicament head on, the Department must take a new perspective on how it supports research.

Essentially, DOE's research is segmented into two parts. The Office of Science supports basic research. Applied research is conducted in the offices organized around fuel sources, such as Energy Efficiency and Renewable Energy, Fossil Energy and Electricity Delivery and Energy Reliability.

These research programs conduct high quality and important work. However, gaps and shortcomings exist. For example, the Office of Science, which has long been the key federal sponsor of physical sciences research, does not have the opportunity to cover all fields—often leaving important disciplines, such as nuclear energy and environmental sciences, insufficiently addressed. Furthermore, there is little communication or coordination between the offices responsible for the two types of research supported by DOE. Another critical aspect of DOE research is that its structure is almost completely focused on supporting its very costly National Laboratories, to the exclusion of universities and the private sector. Nearly half the DOE Science research and development budget goes to operating and constructing facilities.[5]

The National Laboratories play a vital role in a wide range of important issues such as nuclear weapons development, energy security, computational power, new energy sources, determining molecular structure, and homeland security. They set standards, plot specific directions the energy community should follow, implement solutions and provide massive and often costly resources to bear on energy problems. However, these large-scale facilities are not organized, nor structured, to conduct high-risk transformational research in an agile and unbureaucratic manner—nor do their missions cover finding revolutionary ways of solving energy problems.

Furthermore, historically, federal programs in which universities and the National Laboratories are both allowed to compete are heavily dominated by the Laboratories. Particularly, universities are often not provided with adequate resources to contribute to solving larger problems. This discourages creativity and novel ideas that naturally emerge from the enormous intellectual resources that exist in our academic institutions.

In contrast, DARPA has succeeded because it brings "new blood" at comparatively low prices into the defense field by focusing its awards almost entirely on universities and individual companies. Indeed, over the last 10 years, less than five percent of the DARPA budget has gone to DOD labs, the reminder being split approximately two to one for industry and academia.[6] To achieve the same degree of sus-

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[4] American Association for the Advancement of Science, *DOE Science Leads the Pack in 2008,* Washington, DC (March 21, 2007), page 6.

[5] Ibid, page 2.

[6] Kei Koizumi, American Association for the Advancement of Science, Washington, DC (April 19, 2007); and National Science Foundation, Division of Science Resources Studies, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1951–2002,* Arlington, VA (August 2003).

tained success as DARPA, ARPA–E must follow a similar model. That is, to guarantee that ARPA–E truly encourages cutting-edge research, the role of the National Laboratories in this new agency must be limited. Only in unique cases should the national laboratories, in partnership with private and educational enterprises, be recipients of ARPA–E funds.

The institutional knowledge of the Labs, however, could play a constructive role. With their advice, ARPA–E could define new challenges to be addressed. These projects would then be subcontracted out to the most innovative and cost-effective members of the broadest sector of the energy community.

Guaranteeing a Strong ARPA–E

Other improvements are necessary to solidify ARPA–E's leadership in innovative energy research. I will briefly touch on a few of them. For example, to ensure that the agency does not become subordinate to larger DOE research and development entities, the agency's head should report directly to the Secretary of Energy. This again follows the DARPA model, where the Director reports to the Secretary of Defense. Also, a cap on the number of personnel and a relatively short term of service would help keep ARPA–E dynamic and flexible, supported by a continual infusion of new ideas.

Furthermore, adequate funding would be essential. In a tight budget, this will be hard to come by, but the necessity of acting on changing our energy dependencies is of deep national and global concern, and hence the time to act decisively is upon us now. In addition to a "start-up" appropriation from Congress (one that would not be found by 'taxing' existing DOE agencies and labs), independent revenue streams should be considered. These include a trust fund set up from federal oil and gas royalties.[7] Another suggestion is adoption of a macro-pricing system for carbon, such as a cap and trade program, by the United States to address global warming threats.[8]

Finally, steps must be taken to ensure that DOE does not then use ARPA–E's grants, cooperative agreements or contracts to return funds back into DOE. DOE should ensure that most of the agency's budget is spent outside of the Department—whether at universities, large energy companies, start-ups or consortia of academia and industry.

Conclusion

Thank you again for the opportunity to testify today. I look forward to continuing this discussion. Bringing alternative energy technologies to the marketplace is vital as the Nation faces the likely collapse of our traditional fossil fuel economy in the not-too-distant future. There is much to be done, with no apparent simple solution, but our nations health can only be assured by making the shift away from a dominant reliance on these fuels our top priority. ARPA–E would play a central role in finding the tools to make this shift.

There is no doubt that successfully creating a new agency at DOE will face profound challenges. It will require careful writing of legislation and directives, sufficient funding, and an energetic and creative staff. But it must be done. If truly given the opportunity, ARPA–E could make a significant contribution to our national energy solutions.

BIOGRAPHY FOR STEPHEN R. FORREST

Education: B.A. Physics, 1972, University of California, M.Sc. and Ph.D. Physics in 1974 and 1979, University of Michigan. First at Bell Labs, he investigated photodetectors for optical communications. In 1985, Prof. Forrest joined the Electrical Engineering and Materials Science Departments at USC where he worked on optoelectronic integrated circuits, and organic semiconductors. In 1992, Prof. Forrest became the James S. McDonnell Distinguished University Professor of Electrical Engineering at Princeton University. He served as director of the National Center for Integrated Photonic Techology, and as Director of Princeton's Center for Photonics and Optoelectronic Materials (POEM). From 1997–2001, he served as the Chair of the Princeton's Electrical Engineering Department. In 2006, he rejoined the University of Michigan as Vice President for Research, and as the William Gould Dow Collegiate Professor in Electrical Engineering, Materials Science and Engineering, and Physics. A Fellow of the IEEE and OSA and a member of the National

[7] Melanie Kenderdine, Gas Technology Institute, "Hearing on ARPA–E Before the House Committee on Science" (March 9, 2006), page. 6.

[8] William Bonvillian, letter to the House Science and Technology Committee, April 2, 2007, page 14.

Academy of Engineering, he received the IEEE/LEOS Distinguished Lecturer Award in 1996–97, and in 1998 he was co-recipient of the IPO National Distinguished Inventor Award as well as the Thomas Alva Edison Award for innovations in organic LEDs. In 1999, Prof. Forrest received the MRS Medal for work on organic thin films. In 2001, he was awarded the IEEE/LEOS William Streifer Scientific Achievement Award for advances made on photodetectors for optical communications systems. In 2006 he received the Jan Rajchman Prize from the Society for Information Display for invention of phosphorescent OLEDs, and is the recipient of the 2007 IEEE Daniel E. Nobel Award for innovations in OLEDs. Prof. Forrest has authored ~400 papers in refereed journals, and has 155 patents. He is co-founder or founding participant in several companies, including Sensors Unlimited, Epitaxx, Inc., Global Photonic Energy Corp., Universal Display Corp. (NASDAQ: PANL) and ASIP, Inc. (now Apogee Photonics).

Chairwoman GIFFORDS. Thank you, Dr. Forrest. Dr. Van Atta.

STATEMENT OF DR. RICHARD VAN ATTA, RESEARCH STAFF MEMBER, SCIENCE & TECHNOLOGY POLICY INSTITUTE, INSTITUTE FOR DEFENSE ANALYSES

Dr. VAN ATTA. Thank you very much, Madam Chairman and Congressman Inglis.

I kind of come at this from the standpoint of a historical perspective, and I guess also a security perspective, since I have been involved in national security issues and concerns for most of my career at the Institute for Defense Analyses, and now at the Science & Technology Policy Institute. My testimony here is my own views, not of those two organizations.

We have heard a lot about the interrelationship between the universities and the private sector and finance here, and in fact, the generation of this community of interest around key, crucial problems is one of the major advantages, and I would say one of the major breakthroughs, in terms of innovation that DARPA created for the country.

In fact, one of the examples is the relationship between Stanford University and Kleiner Perkins, with the development of a program by DARPA, called the Stanford University Network, which became Sun Microsystems, is an example of one of many of these types of fundamental new relationships that was created, and the new products and capabilities that came from that.

My testimony covers the following questions. First of all, how similar are the types of research that DARPA has engaged in over the past, and the issues of addressing energy and environmental concerns. Second, what are DARPA's key organizational features that have contributed to its success, and could those features be replicated within the political and economic environment surrounding energy and environment? Third, are DARPA's cultural features, which Bill Bonvillian specifically referred to, and central to DARPA's success, replicable within the energy environment?

Others have recognized that energy and environment are issues that are very different in some ways from that which DOD and DARPA confronted. We had a well-defined, known enemy that galvanized our issues and concerns, that in fact, we could say our nation's future was at stake. I think the panel here has tried to make something very clear, which I try to make clear in my classes at Georgetown on emerging technologies and security, and that is energy and environment is now a security issue, a fundamental en-

ergy security issue, that is worth the kind of investments and focus of our attentions that we are talking about today.

My testimony covers several things that are historical in nature, in terms of the DARPA model. What is the DARPA model? Also, the basic question of, which DARPA? Because of the things which many people don't realize or understand is that one of the key elements of DARPA is its flexibility and adaptability. It has moved across the spectrum. It has done many different things, ranging all the way from the most advanced research in things that are today equivalent to nanotechnology and biotechnology and in microelectronics, to applications of true weapons systems in the field, as with the DARPA Project AGILE in Vietnam. So, it is a mistake to say that DARPA is only one thing. It is a flexible, adaptive entity, seeking to apply the best technological innovation to the most daunting problems in the defense world.

DARPA's successes are well known. We have talked about the Internet, their stand-off precision strike, their Stealth. One of the most impressive things about those is the range that they encompass. The other thing is the scale that they encompass. Stealth itself, implemented in four years by DOD after the HAVE BLUE proof-of-concept demonstration, changed the way in which we confronted the Soviets, and in fact, created a secret weapon. The Internet, through the iterative development of new technologies, was based upon J.C.R. Licklider's vision of man-computer symbiosis. We are still getting there.

But we have to understand that these are all based upon visions and scopes of change-state capabilities that would make a fundamental difference. I think we can come up with the same notions in the energy world, in terms of changing the way in which we deal with our energy and our economy, in an affordable and effective livable manner.

And then, we can say that, you know, the DARPA activities that we have talked about, in terms of its culture and all, that was developed over time, but I think the most important characteristics of that which we can talk about, are first of all, that it was independent of the other existing organizational structures. In that case, it was the military services. The military service R&D structures dominated and were dominated by their own priorities—ships and airplanes and tanks. DARPA created a whole new set of capabilities, in terms of missiles and satellites, in terms of the Internet and communications systems, in terms of joint technological capabilities like the stand-off precision strike capabilities with the JSTARS and things like that.

The services would not have done those. It was not in their interest. It was not in their funding portfolios, and only a new organization on the outside could do that. I think when we look at the energy environment, we can say that the existing energy systems and providers will not create those new breakthrough capabilities, or are unlikely to do so without this kind of external capability providing support for it. We are talking here about what is often called high risk, high payoff research. DARPA program managers are encouraged to challenge existing approaches, and seek results, rather than just explore ideas. In fact, one of the concerns earlier in this history that Johnny Foster, as the Department of Defense's Chief

Technology Officer of the DDR&E, exclaimed as a real concern was that DARPA was becoming DOD's NSF, and the point here is that DARPA must stick to its mission. It must stick to its future of applying new technologies, not just playing with new things.

That expectation is built within the culture, and within the program managers themselves. It is designed, in that sense, to be something very different, and as Peter Cannon, who was the head of Rockwell Sciences, in some work with me said, basically, in order to do something different, you have got to do something different, and that is what this is all about, I think.

If you think that the current incremental and traditional approaches of science and technology are meeting our energy problems, fine. If you don't think so, then we have to think of new ways of doing things. We need to innovate in our organizational structures, as well.

I will pass over the discussions I have about the origins of DARPA and all, because you know that, and we have heard some about it. I do want to emphasize that as you look at DARPA, you have to look at some key characteristics, and Bill has already mentioned some of those, and Dr. Forrest as well. First of all, it is independent, purposely and decisively so, meaning that it only reports to the top, and it doesn't go through a lot of bureaucracy. Keeping it from that bureaucracy is crucial and important. It is lean and agile, with a risk-taking culture. It is tolerant of failure, and open to learning. DARPA actually iterates ideas. Dr. Tether, who I just recently interviewed, talked about how they are revisiting artificial intelligence, under the terms cognitive computing. They did work in AI, succeeded to a point, came back, and now are looking at it again. So it is also open to iterating in the ideas as well. It has learned to manage risk, not avoid it.

The DARPA program manager is, in fact, the key. He or she is the technical champion who conceives and owns the program. He is not told what to do, though he does have to have approval from his office director, and from the DARPA Director. Once he starts that program, it is his, and he makes it happen, and he has to make the choices involved in that. So, in essence, they are risk-taking, idea-driven entrepreneurs heading up their own practice. It is an idea-driven and outcome-oriented organization, where the gating notion isn't that the idea is well-proven, but that it has high prospects for making a difference. The research is outcome-driven, to achieve results towards an identifiable goal, not to pursue science per se.

So, when I look at this, and I say what kinds of things are going on, or have gone on in DARPA that have made it successful, I would say is that it is not identified as success because of a particular program or a particular technology, but rather, it is successful for its ability to rapidly take on and assess new ideas and concepts, directing towards daunting challenges, and evaluate and test those in a rapid manner.

Those are the kind of things that we want to create. So, if we want to do that, what are the kind of roles? First of all, there is a fundamental role of finding the new ideas, turning basic science into emerging technologies. Second of all, exploring disruptive capabilities, pursuing them to a point of saying can they make a dif-

ference, how can they make a difference? Thirdly, developing a technology strategy around those potential change-state ideas, that can then lead to a broader overall strategy. And finally, fostering a revolution or fundamental transformation in the domain of technology.

So, I would conclude by saying first of all, the kind of things that made DARPA successful, and would make an ARPA–E successful if allowed to do so, would be one, to create the technology surprise, don't just seek it or avoid it, just don't seek to avoid it. Second of all, build a community of change-state advocates, which is what Bill and Mr. Denniston and all pointed to, creating the interrelationship of the people who want to make a difference. DARPA had more success in terms of finding a community of innovative people, who could both think of the ideas and implement and integrate those ideas, than any other organization I can think of. Third, defining fundamental challenges, developing solution concepts, working in concert with experts, and then, developing demonstrations of them.

This demonstration role is crucial, but you also have to be careful to bound those, so that you don't become caught in the massive draw of funding major demonstrations that keep asking for more and more money. DARPA has had a problem itself in modulating the scale and scope of those demonstration programs, and in the energy area, these could be daunting and very expensive. I think you will have to find a way of doing what DARPA did, which says our demonstrations are proof-of-concept. Implementation demonstrations need to go somewhere else. Finding mechanisms to do that is a crucial issue, and one that goes to the point that Congressman Inglis was saying, which is that commercialization implementation mode.

Something I want to emphasize, and that is, DARPA does not work in a vacuum. It works in a science and technological ecostructure, both in the DOD and outside, in terms of NSF, et cetera. You cannot expect an ARPA–E to succeed if it is only there by itself. It has to be done within a strategy, and within a concept of leadership, drawing upon the science and technology strengths across the whole country.

I hope these ideas have at least given you some concepts of the prospects of successfully implementing an ARPA–E. I will be happy to answer any questions you have.

[The prepared statement of Dr. Van Atta follows:]

PREPARED STATEMENT OF RICHARD VAN ATTA[1]

With energy and climate issues increasingly the focus of public policy discussions, the notion that a special research organization—referred to as ARPA–E—should be created has been proposed in several venues, including H.R. 364. More specifically, there have been calls to create a new entity, modeled on the notably successful Defense Advanced Research Projects Agency, DARPA, to perform advanced R&D di-

[1] Richard Van Atta is a research staff member at the Science and Technology Policy Institute of the Institute for Defense Analyses. The views expressed in this testimony are his own and they do not represent the views of the Institute for Defense Analyses, the Department of Defense or any other individual or organization.

rected at finding technological solutions to energy security and environmental challenges.[2]

Having spent a fair amount of time looking at DARPA's research program over the years I have been asked what would it take for such an organization to be established and be successful drawing from the historical perspective of the unique organization that it would emulate—DARPA. This will be the focus of my remarks today.

Some key questions we might consider are:

1. How similar are the type of research tasks of DARPA to those entailed in addressing energy and the environment and how are they different?
2. What are DARPA's key organizational features that have contributed to success and could those features be replicated within the political and economic environment surrounding energy and the environment in the executive branch, Congress, and private industry?
3. Are DARPA's 'cultural features' that have been central to its success reproducible under the various possible contemporary arrangements for addressing energy and the environment?

Understanding DARPA

We begin this discussion with the following questions:

— What is the "DARPA Model," which, as we will explain, raises the question "Which DARPA?"

— What was the original charter of DARPA and how has it evolved?

— What have been DARPA's "successes"—why is it so well regarded?

— What is the basic "motif" of DARPA success and what are key factors in achieving success?

— What is relevance of DARPA model for other policy areas—particularly energy and climate research?

The "DARPA Model"

DARPA's primary mission is to foster advanced technologies and systems that create "revolutionary" advantages for the U.S. military. Consistent with this mission, DARPA is independent from the military Services and pursues higher-risk research and development (R&D) projects with the aim of achieving higher-payoff results than those obtained from more incremental R&D. DARPA program managers are encouraged to challenge existing approaches to war fighting and to seek results rather than just explore ideas. Hence, in addition to supporting technology and component development, DARPA has on occasion funded experiments in the integration of large-scale "systems of systems" in order to demonstrate what we call today "disruptive capabilities."

Underlying this "high-risk—high payoff" motif of DARPA is a set of operational and organizational characteristics that many have referenced. These include its relatively small size; its lean, non-bureaucratic structure; its focus on potentially change-state technologies; its highly flexible and adaptive research program.

What is important to understand at the outset is that in contrast to the then existing Defense research environment, ARPA was manifestly different. It did not have labs. It did not focus on existing military requirements. It was separate from any other operational or organizational elements. It was explicitly chartered to be different, so it could do fundamentally different things than had been done by the Military Service R&D organizations.

The reason for this dramatic departure was that President Eisenhower and his key advisors had determined that the existing R&D system had failed to respond to the realities of the emerging national security threat embodied by the Soviet Union. This threat was manifest in a crescendo event—the launching in 1958 of the Sputnik satellite. The response to this was not only the creation of a research entity to perform research that others had not adequately pursued, but to embed this organization within a newly created oversight structure reporting to the Secretary of Defense—namely the Director, Defense Research and Engineering, or DDR&E.

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[2] The DARPA model—sometimes referred to as ARPA–E, or E–ARPA—has been suggested in several venues, most notably in the National Academies' *Rising Above the Gathering Storm, Energizing and Employing America for a Brighter Economic Future,* National Academies, Committee on Science, Engineering, and Public Policy (COSEPUP), 2006.

DARPA's origins: Strategic Challenges ~1958

ARPA[3] was initially chartered in response to the orbiting of the Sputnik satellite, which raised the specter of the Soviet Union as a technological as well as political threat to the United States. Sputnik itself demonstrated that the USSR not only had ambitions in space, but also had developed the wherewithal to launch missiles with nuclear capabilities to strike the continental United States. Therefore, at the outset ARPA was focused initially on three key areas as Presidential Issues: space, missile defense and nuclear test detection.

- Regarding the first issue, space, soon after its birth a large element of ARPA was spun off to become NASA, based on President Eisenhower's determination that space research should not be directly under the DOD.[4]
- By 1959 ARPA had assignments on ballistic missile defense (DEFENDER) and nuclear test detection (VELA), and also pursued research in solid propellant chemistry, and materials sciences. Soon after ARPA initiated a program on information processing "techniques" with a focus on possible relevance to command and control also began. These became the major elements of ARPA's program over the next decade.
- Based on the initiative of Director of Defense Research and Engineering (DDR&E), John S. Foster, a counter-insurgency program (AGILE) was started as the Vietnam War heated up.

DARPA was first established as a research and development organization immediately under the Secretary of Defense, reporting to the Director of Defense Research and Engineering, then the third highest official in the department with the mission to

— assure that the U.S. maintains a lead in applying state-of-the-art technology for military capabilities

and

— prevent technological surprise from her adversaries.

DARPA's Unique Mission

ARPA was created to fill a unique role, a role which by definition and in its inception put it into contention and competition with the existing Defense R&D establishment. As the *Advanced Research* Projects Agency, ARPA was differentiated from other organizations by an explicit emphasis on "advanced" research, generally implying a degree of risk greater than more usual research endeavors. Former ARPA Director Dr. Eberhardt Rechtin emphasized that research, as opposed to development, implies unknowns, which in turn implies the possibility of failure, in the sense that the advanced concept or idea that is being researched may not be achievable. Were the concept achievable with little or no risk of failure, the project would not be a *research* effort, but a *development* effort.

DARPA over its history has grappled with how to interpret or pursue *advanced* research, both in contrast to the broad array of research being conducted within and for DOD, and relative to its perception of the needs at the time.

Recently DARPA stated its mission as follows:

> DARPA is a Defense Agency with a unique role within DOD. DARPA is not tied to a specific operational mission: DARPA supplies technological options for the entire Department, and is designed to be the "technological engine" for transforming DOD. . .. a large organization like DOD needs a place like DARPA whose only charter is radical innovation. DARPA looks beyond today's known needs and requirements.

It is clear from DARPA's history that within the scope of this mission the emphasis and interpretation of advanced research have varied, particularly in terms of (1)

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[3] The original name, Advanced Research Projects Agency, ARPA, was changed in 1972 to *Defense* Advanced Research Projects Agency, DARPA. Briefly in 1993–95 the Clinton Administration reverted back to ARPA, but in 1996, the Congress mandated that the name be changed back to DARPA. In historical references I use the name of the organization at that time, either ARPA or DARPA, but for general discussion the current title, DARPA, is used.

[4] Herbert York states it was well understood in ARPA that its broad role in space programs was temporary, with the creation of NASA already in the works both in the White House and in Congress, see Herbert York, *Making Weapons, Talking Peace,* Basic Books, New York, 1987, p. 143.

the degree and type of risk[5] and (2) how far to go toward demonstration of application. At times with changing circumstances the agency has had to reassess its project mix and emphasis due to determinations both internally and within the Office of the Secretary of Defense regarding the appropriate level of risk and the need to demonstrate application potential. In a sense these somewhat contradictory imperatives serve as the extreme points on a pendulum's swing. As DARPA is pulled toward one of the extremes, often by forces beyond itself, including Congressional pressures, there are countervailing pressures stressing DARPA's unique characteristics to do *militarily relevant advanced research.*

At the other end of the spectrum, as projects demonstrate application potential, DARPA runs into another set of tensions, not with the researcher, but with the potential recipient of the research product. Given that the ideas pursued are innovative, perhaps revolutionary, they imply unknowns to the user in terms of how they will be implemented and how this implementation will affect their, the implementer's, overall operations. To this end the potential users seek to reduce their uncertainty, in what is a highly risk-intolerant environment, by encouraging DARPA, or some other development agency, to carry forward the concept until these risks are minimized, or simply ignoring, delaying or stretching out its pursuit. While achieving transition can be increased by additional risk reducing research, this also entails substantial additional cost and raises the issue of mission boundaries.

There have been several occasions in DARPA's history when its management has determined that it has done enough in an area to demonstrate the potential of a specific concept—such as Unmanned Air Vehicles (UAVs)—and that it is thus time for others to fund development of its application and acquisition. These decisions have at times resulted in a potential concept becoming a victim of the "valley of death," with the application either failing to be realized, or, as in the case of UAVs, taking over a decade with special high-level attention of OSD to come to fruition. Developing mechanisms to engage potential "customers" in an emerging concept and working with these prospective developers and users as the ideas mature is a key aspect of DARPA project management.

DARPA's Key Characteristics

It was recognized from the outset that DARPA's unique mission required an organization with unique characteristics. Among the most salient of these:

- **It is independent from Service R&D organizations**

DARPA neither supports a Service directly nor does it seek to implement solutions to identified Service requirements. Its purpose is to focus on capabilities that have not been identified in Service R&D and on meeting defense needs that are not defined explicitly as Service requirements. This does not mean that DARPA does not work with the Services, but it does mean that it does not work the requirements that drive Service R&D.

- **It is a lean, agile organization with risk-taking culture**

DARPA's charter to focus on "high risk; high payoff" research requires that it *be tolerant of failure and open to learning.* It has had to learn to manage risk, not avoid it. Because of its charter, it has adopted organizational, management and personnel policies that encourage individual responsibility and initiative, and a high degree of flexibility in program definition. This is one reason that DARPA does not maintain any of its own labs.

A primary aspect of DARPA's lean structure is that it centers on and facilitates the initiative of its Program Managers. **The DARPA Program Manager is the technical champion who conceives and owns the program.** As the Program

[5] Risk has several dimensions: (1) lack of knowledge regarding the phenomena or concept itself; (2) lack of knowledge about the applications that might result if the phenomena or concept were understood; (3) inability to gauge the cost of arriving at answers regarding either of these; and (4) difficulty of determining broader operational and cost impacts of adopting the concept. As answers about (1) become clearer through basic research, ideas regarding applications begin to proliferate, as do questions of whether and how to explore their prospects. DARPA is at the forefront of this question and has the difficult job of determining whether enough is known to move toward an application and, if so, how to do so. At times this can be very controversial, as researchers may feel they do not know enough to guarantee success and are concerned that "premature" efforts may in fact create doubts about the utility and feasibility of the area of research, resulting in less funding and (from their perspective) less progress. DARPA, however, has a different imperative than the researcher to strive to see what can be done with the concepts or knowledge, even if it risks exposing what is not known and what its flaws are. This tension is endemic in DARPA's mission and at times has put it at odds with the very research communities that it sponsors.

Manager is the guiding intelligence behind the program, the most important decisions of DARPA's few Office Directors are the selection of and support of risk-taking, idea-driven Program Managers dedicated to making the technology work.

- **It is idea-driven and outcome-oriented**

The coin of the realm at DARPA is promising ideas. The Project Manager succeeds by convincing others—the Office Director and the DARPA Director—that he or she has identified a high potential new concept. *The gating notion isn't that the idea is well-proven, but that it has high prospects of making a difference.* The DARPA Program Manager will seek out and fund researchers—usually in competition with one another—within U.S. defense contractors, private companies, and universities to bring the incipient concept into fruition. Thus, the research is out-come driven to achieve results toward identified goals, not to pursue science per se. The goals may vary from demonstrating that an idea is technically feasible to providing proof-of-concept for an operational capability. To achieve these results the Program Manager needs to be open to competing approaches, and be adroit and tough-minded in selecting among these.

Which DARPA?

While the concept of DARPA as a "high-risk—high pay-off" organization has been maintained, it also has been an intrinsically malleable and adaptive organization. Indeed DARPA has morphed several times. DARPA has "re-grouped" iteratively—often after its greatest "successes." The first such occasion was soon after its establishment with the spinning off of its space programs into NASA. This resulted in about half of the then ARPA personnel either leaving to form the new space agency, or returning to a military service organization to pursue military-specific space programs. A few years later then DDR&E John S. Foster required ARPA to transition its second largest inaugural program—the DEFENDER missile defense program—to the Army, much to the consternation of some key managers within ARPA. Also early in its history ARPA was tasked by Foster, acting at the behest of Secretary of Defense McNamara, to conduct a program of applied research in support of the military effort in Viet Nam. At the same time ARPA began what was to become its most famous program—the information technology program that among other things spawned the Internet.

More important than the variety of the programs is that they demonstrate the quickness that DARPA took on a new initiative and also how rapidly its programs will move—sometimes more rapidly than its supporters within DARPA desire. However, rather than particular programs or technologies becoming the identifier of what DARPA is, its key distinguishing characteristic is its rapidly taking on and assessing new ideas and concepts directed at daunting military challenges or overarching application prospects. While the dwell time on new ideas may vary and DARPA may return to the concept iteratively over its history—most notably with its return to missile defense in the 1970s leading to SDI in the 1980s—its hallmark is to explore and create new opportunities, not perfect the ideas that it has fostered.

This quick synopsis of DARPA's history leads to me to the conclusion:

There is not and should not be a singular answer on "what is DARPA"—and if someone tells you that—they don't understand DARPA.

DARPA's unique focus is "high risk—high payoff" research. But, clearly this has not been the only focus. Moreover, the content and focus of that research has changed with the circumstances and need. A crucial element of what has made DARPA a special, unique institution is its ability to re-invent itself, to adapt, and to avoid becoming wedded to the last problem it tried to solve.

DARPA roles

While we have emphasized DARPA's adaptability, this is not to say that there aren't some underlying elements to what DARPA does. While there have been some additional ad hoc activities thrown in over time, such as its oversight of SEMATECH, DARPA has had significant roles—with a varying mix—in the following:

- Turning basic science into emerging technologies
- Exploring "disruptive" capabilities (military and more generic)
- Developing technology strategy into a Defense strategy
- Fostering revolution or fundamental transformation in a domain of technology application (e.g., the Internet or stand-off precision strike).

Key elements of DARPA's success

There are several key elements in DARPA's succeeding in its unique role as an instigator of radical innovation.

- **Create surprise; don't just seek to avoid it**

  DARPA mission is to investigate new emerging technological capabilities that have prospects to create disruptive capabilities. It is differentiated from other R&D organizations by a charter that explicitly emphasizes "high-risk, high payoff" research.

- **Build communities of "change-state advocates"**

  DARPA program managers may often themselves foster a specific concepts or technological approach that they seek to explore and develop. But they almost never are they main, let alone sole, investigator of the notion. Rather it is DARPA's motif to instigate cooperation among a group of forward-looking researchers and operational experts. In this sense, **DARPA's success depends on it being a leader and catalyst in developing this community of interest.**

- **Define challenges, develop solution concepts, and demonstrate them**

  One aspect of DARPA's success has been efforts to define strategic challenges *in detail.* Since its inaugural Presidential Issues, DARPA has been problem focused, seeking breakthrough change-state approaches to overcome daunting issues. This has been true in the military realm from the outset. DARPA-sponsored researchers under Project DEFENDER conducted detailed assessments of intercontinental missile phenomena for both defense and offense.[6] Later in the late 1970s, DARPA funded studies to understand how the Warsaw Pact was postured against Western Europe in order to determine how technology could provide a means to offset the Warsaw Pact's numerical and geographic advantages. This planning led to DARPA research in both stealth and stand-off precision strike, which provided the basis for Secretary of Defense Harold Brown's and Director of Defense Research and Engineering William Perry's "Offset Strategy."[7]

  Such detailed conceptual work also facilitated DARPA's non-military research—explicitly that in information technology. JCR Licklider came to DARPA as head of the Information Processing Techniques Office with a vision on man-computer symbiosis that grew in specificity as he collaborated with others, especially Robert Taylor, to present a perspective of internetted computers providing capabilities for collaboration and data interchange amongst researchers.[8] Overtime IPTO grew this initial concept into an increasingly inter-connected strategy.

Tension between DARPA roles

DARPA has been a pursuer of new breakthrough technologies *independent of defined needs.* It also has been a developer of concept prototypes and demonstrations that *address needs* (but not defined requirements). While complementary, these are substantially different roles requiring different management approaches and different types of researchers. The first type of endeavor requires an exploratory, somewhat unstructured approach seeking out alternatives amongst competing ideas. The latter focuses on taking a specific set of emerging capabilities and combining them into a demonstration of proof-of-concept. Such demonstrations are generally larger in scale and more resource intensive than exploratory research. Moreover, rather than exploratory, they are aimed at assessing the merit of a specific concept. Indeed, demonstration prototype efforts can be "resources sumps," as they are both uncertain and costly. Therefore the DARPA Director has needs to attentively oversee these while maintaining and protecting the more exploratory research efforts.

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[6] For example, in the 1960s and 1970s DARPA funded studies at the then new Institute for Defense Analyses on missile offense and defense first under the STRAT–X project on ICBM offense-defense followed by then PEN–X study which assessed both U.S. and Soviet capabilities to penetrate missile defense systems.

[7] Richard Van Atta and Michael Lipptiz, Transformation and Transition: DARPA's Role in fostering an Emerging Revolution in Military Affairs, IDA Paper P–3698, (Alexandria, VA: Institute for Defense Analyses, March 2003).

[8] JCR Licklider, "Man-Computer Symbiosis," *IRE Transactions on Human Factors in Electronics,* volume HFE–1, pages 4–11, March 1960 and JCR Licklider and Robert Taylor, "The Computer as a Communications Devise," *Science and Technology,* April 1968.

DARPA's Successes

Over the nearly fifty years since its inception DARPA has had several major accomplishments that distinguish it as an innovative organization. While these have been recounted elsewhere, it may be useful here to summarize to illustrate the scale, scope, and varying types of innovative capabilities that DARPA helped to instigate.[9]

3rd Generation Info Tech-the Creation of Interactive Information[10]

The singularly most notable technology accomplishment that DARPA is known for is the development of what is now known as modern computing, as embodied in the personal computer and the Internet. While this achievement had its origins in remarkable vision of one man, JCR Licklider, its coming to fruition speaks volumes for the nature of DARPA as an organization and the willingness of its management to support and nurture the pursuit of such an extraordinary perspective.

The vision that Licklider brought to DARPA was one of a totally revolutionary concept of computers and how they could be used. He foresaw that rather than being fundamentally highly automated calculating machines, computers could be employed as tools in supporting humans in creative processes.[11] However, to do so would require entirely new, yet non-existent computer capabilities that included the underpinnings for:

- interactive computers
- Internetted computing
- Virtual reality
- Intelligent systems

Licklider's extraordinary notion of "man-computer symbiosis" was a fundamental vision that foresaw using new types of computational capabilities to achieve first augmented human capabilities and then possibly artificial intelligence.

He then identified prerequisites that were the underpinnings for this entirely new approach to using computers, which included:

— Entirely new types of data-processing equipment and programs that facilitated researchers interacting with their computers in real-time.

— Taking advantage of the speed mismatch between the computer, which can perform nearly instantaneously and the slower and more deliberative human. To overcome this mismatch, the computer must divide its time amongst several users [the concept of time-sharing].

— The creation of the "Thinking Center" "a Network of libraries and information storage connected by wideband communications. . .to individual users"

— Memory and memory organization developed and optimized for search and retrieval

— Entirely different computer language that is "goal oriented" rather than step by step process oriented

— Completely novel input and output mechanisms to overcome the cumbersome punch cards and reams of computer printout with such radical notions as touch-screen displays and even speech recognition.

Licklider brought these inchoate notions to DARPA when he was named Director of its Information Processing Techniques Office (IPTO). He brought a powerful vision of what could be and used this as the basis for sustained investment in the underlying technologies to achieve the vision. These investments were aimed at adventurous innovators in academia and in industry—mostly small enterprises on the fringe of the information processing industry then dominated by IBM, such as Bolt,

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[9] DARPA's most notable past technical accomplishments have been documented in several prior studies. For an overview of many of DARPA's programs from its inception see Richard Van Atta, et al., *DARPA's Technical Accomplishments,* Volumes I–III, IDA Papers P–2192, 1990, P–2429, 1991, and P–2538, 1991. For a more in-depth review of a set of key programs in the 1970s and 1980s that had transformational impact on U.S. military capabilities see Richard Van Atta and Michael Lippitz, et al., *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs,* IDA Paper P–3698, (Alexandria, VA: Institute for Defense Analyses, March 2003). DARPA's formative role in information technology has been reviewed in detail by Arthur L. Norberg and Judy E. O'Neill. *Transforming Computer Technology: Information Processing for the Pentagon, 1962–1986* (Baltimore, 1996) and M. Mitchell Waldrop, *The Dream Machine: JCR Licklider and the Revolution that Made Computers Personal,* New York Viking Penguin, 2001.

[10] M. Mitchell Waldrop. *The Dream Machine.*

[11] JCR Licklider, "Man-Computer Symbiosis."

Baranek and Newman (BBN). Moreover, there was an underlying concept of how this investment would lead to applications relying on an entrepreneurial dynamic. This effort became the gestation of a concerted effort that culminated in the ARPANET, as well as a number of technological innovations in the underlying computer graphics, computer processing, and other capabilities that led to **DARPA's fundamental impact on "making computers personal". . .a truly change-state vision which had fundamental impact in fostering a transformational concept and the creation of an entire industry.**

DARPA's Role in Creating a Revolution in Military Affairs[12]

DARPA has been instrumental in developing a number of technologies, systems and concepts critical to what some have termed the **Revolution in Military Affairs** (RMA) that DOD implemented in the 1990s based on R&D DARPA conducted over the prior fifteen years. It did so by serving as a virtual DOD corporate laboratory: a central research activity, reporting to the top of the organization, with the flexibility to move rapidly into new areas and explore opportunities that held the potential of "changing the business." It was a virtual laboratory because DARPA did not perform research directly but rather acted as a catalyst for innovation by articulating thrust areas linked to overall DOD strategic needs, seeding and coordinating external research communities, and funding large-scale demonstrations of disruptive concepts. In doing so, the DARPA programs presented senior DOD leadership with opportunities to develop disruptive capabilities. When these programs received consistent senior leadership support, typically from the highest levels of the Office of the Secretary of Defense, they transitioned into acquisition and deployment. At other times, without this backing from highest reaches of the department, only the less disruptive, less joint elements moved forward.

An example of one of the most successful DARPA programs is its championing of stealth. While a radical and controversial concept, DARPA's stealth R&D had most of the properties listed above. DARPA harnessed industry ideas. Low-observable aircraft had been built before, for reconnaissance and intelligence purposes, but not pursued for combat applications. The Air Force had little interest in a slow, not very maneuverable plane that could only fly at night. After considerable engineering work, the HAVE BLUE proof-of-concept system enabled top OSD and Service leadership to proceed with confidence to fund and support a full-scale acquisition program. OSD leadership kept the subsequent F–117A program focused on a limited set of high priority missions that existing aircraft could not perform well—e.g., overcoming Soviet integrated air defenses—and worked with Congress to protect its budget, with a target completion date within the same administration. The result was a "secret weapon" capability—exactly what DARPA and top DOD leadership had envisioned.

VISION: DARPA conception, development and demonstration of disruptive capabilities

DARPA's higher-risk, longer-term R&D agenda distinguishes it from other sources of defense R&D funding. **Perhaps the most important effect of DARPA's work is to change people's minds as to what is possible.** A fundamental tension for DARPA is balancing its pursuit of high-risk research independent of a defined need with its demonstration of capabilities that address a specific strategic problem (but not defined requirements). Although integration projects may be just as "high risk" as research projects, philosophically, culturally, and managerially, these are very different processes. The DARPA Director needs to mediate between these missions and, more importantly, bridge the two communities. DARPA has been effective in part because a strong axis between DARPA and top OSD leadership formed around ambitious *outcomes,* not technologies per se. An outcome orientation is particularly important in explaining to Congress what DARPA is doing and why.

LEADERSHIP: Acquisition and Deployment of Disruptive Capabilities

DARPA's history shows that *if fielded disruptive capabilities are the objective, it is insufficient for DARPA to create an example and then rely upon the traditional Service acquisition system to recognize its worth and implement it.* Because acquisition and deployment of disruptive capabilities challenge existing programs and bureaucracies, it is difficult to find eager Service customers for them. Also, because new capabilities are not technically mature or operationally robust, the Services will generally be reluctant to take on the significant and potentially costly risk reduction

[12] This section draws upon Richard Van Atta and Michael Lippitz, et al., *Transformation and Transition: DARPA's Role in fostering an Emerging Revolution in Military Affairs,* IDA Paper P–3698, (Alexandria, VA: Institute for Defense Analyses, March 2003).

efforts required to move them into acquisition. Hence, rapid acquisition and deployment of disruptive capabilities requires an integrated and consistent senior leadership effort, typically from the Director of Defense Research and Engineering or the Under Secretary of Acquisition, Technology and Logistics. These senior OSD leaders must judiciously exercise their authority to overcome the resistance of people to new ideas, of acquisition organizations to perceived competition, and of requirements and acquisition organizations to uncertainty and risk.

Energy and the Environment—A DARPA Model?

DARPA's successes in spurring technological innovation have led to numerous calls for applying "the DARPA model" to other issues than national defense. As noted above, one area that has received particular attention is energy technology. Does the DARPA model provide a useful approach to address issues of energy research and development? The foremost question is what is the imperative for radical, transformative R&D in energy technology equivalent to DARPA's national security concern? Are energy security and stemming climate change and its effects comparable motifs?

DARPA is chartered to identify and pursue potential technological capabilities that could provide fundamental advantage to the U.S. relative to existing or potential adversaries. The need to be ahead of all others to "avoid technological surprise" in the interest of national security is a recognized imperative for making exploratory high-risk investments. Do such interests as "energy independence" or ameliorating climate change provide sufficient imperatives for energy-related advanced research?

DARPA has had the imprimatur of the Secretary of Defense to both engage in highly uncertain R&D not explicitly focused on identified requirements and to promote the application of emergent, often disruptive capabilities based on such research. In essence the Secretary of Defense has played the role of the Chief Executive Officer protecting and supporting the Director of DARPA as the director of innovation—seeking new technological capabilities that can redirect and revitalize an enterprise. While the Department of Energy has pursued advanced S&T in its Office of Science, DOE has not had the type of implementation-focused efforts of advanced technology that have been promoted by DOD leadership in bringing DARPA developments into fruition. While DOE clearly has an important, perhaps dominant role in current energy research, and this research has repercussions for climate change, the two are not synonymous. For example, most of the current energy research agenda is driven by energy efficiency and security concerns focusing on incremental improvements of existing approaches. Also, the scope of climate change R&D goes well beyond the scope of DOE.

Thus, the organizational question for "ARPA–E" is much more problematic than that faced by DARPA. DARPA's job explicitly is national security—and the main government focus has been the Department of Defense. DARPA has been stretched into broader venues including support for the intelligence community and also the support of more generic commercially-related programs—at one time labeled "dual use" technologies. The intelligence-related aspects of DARPA, while at times collaborated and coordinated with non-DOD interests, particularly the CIA, are clearly linked to the national security mission and the fact that DOD operates its own vast intelligence operations.

This raises another vexing question: How would results of an Energy ARPA be brought into fruition? DARPA has developed an established network of implementation paths that varied by technology and application. It has developed strategies for interacting with military users and developers for bringing military capabilities into application using the support of OSD when needed. It has developed various mechanisms for supporting incipient technological capabilities in universities and small enterprises and provided systematic support that builds an interlinked set of underpinning technologies that together, iteratively have moved closer to an ultimate transformational vision. Can an Energy ARPA obtain the freedom of movement to organize such implementation focused investment strategies? Who would be the organizations that would take the results of ARPA–E's proof-of-concept research and move it into the next level of development? In creating an ARPA–E how clearly defined should be the mechanisms it would draw upon to move its ideas forward? It would be an unfair reading of history to say that all of this was well understood when ARPA was founded. For the military side of the equation the role of the Secretary of Defense and the DDR&E cannot be overstated. Particularly in the 1960s

through the 1980s OSD interacted closely with the Director of DARPA in laying out priorities and directions—while the Director was clearly responsible for research.[13]

The path undertaken by DARPA in bringing its technical results into application has been that of a somewhat distant or indirect supporter of the implementation process. In essence DARPA's role in technology transition has been to support technology demonstrations often in conjunction with potential users or through a series of "boot strapped" implementations of new technologies by employing the technology development as inputs to other DARPA research. This latter approach has been particularly effective in the area of information processing technologies, where for example, the DARPA-supported computer workstations were specifically acquired for use by DARPA-funded integrated circuit technology development programs.[14] When the results of the technology development most likely would have to be adopted and adapted by the commercial sector the DARPA approach has generally been one of encouragement, but not direct involvement. The concern that commercialization is a function that is best left to others than those in government has led to proposals for creating alternative, non-governmental mechanisms, such as an Energy Technology Corporation, as suggested by John Deutch.[15]

In employing a DARPA-model to another area of research, it is important to understand that DARPA began as relatively small, highly focused organization that was explicitly taking on problems that were of relatively little priority to existing military R&D organizations. Yet, the issues were of great importance and priority to senior leadership—including the Secretary of Defense and the President. Later, as the policy and technological circumstances changed, DARPA morphed and adapted. In particular, DARPA has been focused on pursuing advanced technology projects that could potentially "make a difference"—and wedded not to the success of any particular project. It has been an "innovation farm" and idea incubator. It has only exceptionally taken on the actual implementation of a technology—and then only as a last resort, or as a very incipient step in application prototyping. If another department were to stand up an "ARPA-like" organization, it should not try to invent a full-blown, full scale operation based on DARPA after 30 years. Rather, it should endeavor to build the organization organically, adaptively focusing on explicit high priority mission challenges. The idea should not be to make something look like DARPA; it should be to identify and organize advanced research around imperatives that are similar in nature to those that have driven DARPA.

DARPA has been able to take on high-level issues that are disruptive of current operations and technical interests. The example of stealth, above, shows how it fostered a concept that was received hostilely by the main service that was to employ it—the Air Force—and initially rejected by the Navy. Even in its information technology research DARPA confronted a major, well-ensconced vested interest in IBM, who at the time totally dominated not only the computer industry, but also computer research.[16] Can a civilian organization maintain independence of its technology program from such powerful "vested interests"? DARPA had certain advantages that may be difficult to emulate in a non-DOD organization, particularly today. First, at its inception it had the cover of the initial set of Presidential Issues, vested on it directly from the Secretary of Defense. It was given a charter to take on issues that the existing Service R&D structure had failed to give adequate priority to and the results of which were manifestly wanting. As it successfully addressed its initial set of programs it further gained the support of OSD which gave it the top cover it needed. If an Energy ARPA is to have any chance of success it will need this level of support from both the Secretary of Energy and the White House.

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[13] The interaction between the DARPA director and OSD is important here. This was not a one-way street with OSD handing down specific focus for research, rather it was a dialogue in which the OSD, usually through the DDR&E, today the USD (AT&L), would lay out military and technical challenges it saw as priorities and DARPA would develop its perspective on what emerging technical capabilities might address these. DARPA, often in conjunction with other organizations, such as the Defense Nuclear Agency (DNA), would conduct studies and provide input to high-level DOD leadership on options for addressing daunting strategic concerns.

[14] Van Atta, et al., *DARPA Technical Accomplishments,* Volume II, Chapter XVII, "VLSI : Enabling Technologies for Advanced Computing," Alexandria, VA: Institute for Defense Analyses, April 1991.

[15] John Deutch, "What Should the Government Do To Encourage Technical Change in the Energy Sector?" *MIT Joint Program on the Science and Policy of Global Change,* Report No. 120, May 2005.

[16] See Kenneth Flamm, *Creating the Computer,* Washington, DC: Brookings Institute, 1988, for a discussion of IBM's dominant role in computer research in the early 1960s.

Issues in Establishing an ARPA–E

Some key elements that would need to be addressed, and in some cases directly overcome, if an effective ARPA–E were to be created, are:

1. Leadership support—As discussed above, ARPA had President Eisenhower's direct and strong support, and this support has generally been sustained with both the White House and the Secretary of Defense.
2. Congressional oversight—One issue for ARPA–E, relative to DARPA is that DARPA enjoys Congressional oversight that is relatively simple, and has generally had the backing of key members and staffers.
3. Existing Lab structure—ARPA–E will need to contend with a research infrastructure in the National Laboratories, that had no such precedent in DOD. The Service R&D structure lacked the scale and scope of the current "energy labs" and also the support on Capitol Hill that these labs have.
4. Incumbent business interests—DARPA has succeeded by developing and fostering a community of interest ranging from academics to business. It developed these communities piece by piece from the ground up, based on technological capabilities and prospects. It has been able to find within that community interested and innovative participants who were willing to experiment with new ideas. In its information processing technology development, DARPA was able to build an alternative base despite the dominant presence of IBM. It is unclear whether the firms currently in energy production and usage will be open to such experimentation and whether alternative firms and even alternative sectors can grow within the energy industrial structure.

An Energy ARPA has been proposed as a way to respond to critical energy needs by accelerating research in game-changing technologies. Advocates of this new approach need to make a strong case on what it is they see as needing to be done that the current R&D processes are not doing successfully. In essence, they need the moral equivalent of their Sputnik to galvanize support for such a novel agency. Is the lack of a robust hybrid automobile program in the U.S. an example that has similar sway? Is the hydrogen energy effort in this country similar to the ineffective Service response to Soviet ICBMs in the 1950s to provide a stimulus to creating an Energy ARPA? Is the recognition of the anthropogenic climate change impacts reaching a point where high-level policy-makers have come to realize that incremental approaches based on existing technologies is so insufficient that a radical enterprise is needed?

BIOGRAPHY FOR RICHARD VAN ATTA

Dr. Richard Van Atta is a senior research analyst at the Science and Technology Policy Institute (STPI), where his work focuses on the technological needs and interests of the United States as they affect both national and economic security. He taught courses in national security and policy analysis at the American University's School of International Service followed by several years of private consulting before joining the research staff at the Institute for Defense Analyses (IDA) Studies and Analyses Center (1983–2006). From 1993 to 1998, Dr. Van Atta was an official in the Department of Defense (on temporary assignment from IDA), first as Special Assistant for Dual Use Technology Policy then as Assistant Deputy Under Secretary for Dual Use and Commercial Programs. He also is an adjunct professor in Georgetown University's Security Studies Program teaching a course on Emerging Technologies and Security.

Dr. Van Atta has a Bachelor's Degree in political science from the University of California, Santa Barbara and a Ph.D. in political science from Indiana University.

DISCUSSION

Chairwoman GIFFORDS. Thank you, Dr. Van Atta. We are on a bit of a time crunch, in terms of Mr. Inglis' schedule, so I am going to allow him to start this first round of questions.

NUCLEAR RESEARCH

Mr. INGLIS. Thank you, Madam Chair. Very kind of you to let me go here, and appreciate the testimony.

Mr. Denniston, you said something interesting, that nuclear shouldn't be included. Things that I have heard lately about nuclear. It has been a long time, of course, since we built a nuclear power plant, and I heard a major construction company tell me they're not sure that we have the capacity, that if you look around at who could design them, and that sort of thing, they were expressing some doubt.

In talking to electrical generator kind of companies, people who make electricity, they tell me they are not willing to spend money on research in next generation reactors. If that is the case, we have lost some proficiencies in construction, and we don't have the appetite for research in the private sector, why not include nuclear in ARPA–E?

Mr. DENNISTON. Great question. My answer would be that I am not saying that we shouldn't fund nuclear research. What I am saying is that the narrow purpose and mission, in my view, of ARPA–E, is translational research. Translational research is focused on identifying in the world, in the case of energy, in the commercial-industrial business world, the breakthrough energy solutions that will solve climate change, energy dependence, American competitiveness, and then reaching back to basic science, and identifying the possible solutions, and pushing them forward to the bring of commercialization, which is where industry can take over. And so, DOE can and will fund nuclear research. You can separately discuss what the appropriate funding levels would be.

To the comments that have been made by the panel, the importance of having a focused mission, and of having a consistent culture, and a small, flat, risk-taking organization, are critical to the importance of ARPA–E, as those factors were to DARPA.

And for those reasons, and what I also said in my testimony, Congressman, is that translational research is best suited to identifying breakthrough technologies in emerging fields, and not really design for incremental improvements in existing ones.

TECHNOLOGY COMMERCIALIZATION

Mr. INGLIS. Let me ask, you are here in the Science and Technology Committee, and of course, that means that we want to provide these breakthroughs, or be involved in the breakthroughs, and help, as we push through the barriers. And maybe at Energy and Commerce, they regulate things that already are in existence.

But there is sort of a chicken and egg question here, I think, and that is whether there is technology already available, and what it takes is market forces to force them into a position of being viable in a commercial marketplace. And to some extent, you know, it is, we don't want to do science projects. We actually want to—they are fun and very valuable, but we want to actually get the technology into the marketplace, right? So, anybody want to take a shot at whether that is what we are successfully doing here, or whether really what we should be talking about is some kind of dealing in the marketplace, in terms of the price of gasoline, and things like that, that make it so that technologies would suddenly become very viable.

Dr. FORREST. I would like to make a comment on that, if I may. I tend to agree with part of your question, which is do we know

the scientific and technological routes to make clean energy? The answer to that is by and large, we do. Is it affordable? No, it is not. We are competing against fossil fuel. It is not an even playing field, but that is not the point. We are dealt the playing field that we have.

So the real question is what are the science and technology breakthroughs that will make these solutions affordable? And that is what an independent ARPA–E will do, because it tailors, it brings the innovative engine together with the commercial engine, and you get it to be pulled into the marketplace very rapidly. So, no, we are not at all advocating, I don't believe anybody on this panel is advocating that we create another NSF. That is really, that creates the fundamental base of the technologies that we are talking about. What we are looking at is, and I think Mr. Denniston said it very well, it is this partnership, this translation that takes us from that basis to a market effective economy.

Mr. INGLIS. And Dr. Forrest, actually, you sharpened my question very well, because I don't want to sound like I am opposed to basic research. We here on this committee, we are very excited about basic research, because who knows where it will lead, but it gives us opportunities to pursue. But you are onto, really, the better, more precise question. That is, if you internalize the external cost of those fossil fuels, and made it so the market properly evaluated those, then the question is whether some of those technologies might suddenly become viable.

Dr. FORREST. Well, I certainly would.

Mr. BONVILLIAN. Mr. Inglis, you have asked a very important question. I think the underlying issue here is that there is a variety of things we are going to have to do in this very complex area of trying to stand up technologies within deeply established sectors. And part of that is going to have to be looking at the whole pricing situation, and someday, we will do that.

Within that, though, we have to get the innovation system right, too. If we don't have the innovation system serving up new opportunities, if we only deal with the macro-pricing system, we are still going to be completely behind the eight-ball. If we don't have innovation opportunities that the energy sectors that are going to adopt, and see as ways out of their dilemma, we are just not going to get there.

So, I think the function of this committee is a crucial one in this mix, which is to get the innovation system in the kind of shape we are going to need to allow these technology opportunities to happen. There is a series of problems, as I see it, in the technology standup area. The first set of problems, and to some extent we have emphasized this, is standing up sort of disruptive technologies that are going to be in new areas, and not necessarily compete with established sectors. And there are many of these. And DARPA has done that brilliantly. I mean, it has sold into the Defense Department, but it has also launched many technologies into the private sector, using its model.

But then, in the energy sector, we have got other problems. A lot of what we stand up are going to have to be components in established sectors. So, you think of a battery in a hybrid engine. That is going to be a component in a larger automotive system. You

think of carbon capture and sequestration. Those are components in a much larger utility sector. Some of those sectors are going to be game for adapting new technologies. Some aren't. Some are going to resist this change, and resist it in very tough-minded, competitive ways.

So, we are going to have to figure out how to weave through those areas. I think a translational research entity can play a role, particularly in those sectors where adaptation is going to be accepted. But we need to have technologies for the full range.

There are two other fundamental technology problems here. One is in the conservation and efficiency side. Some of that will involve breakthrough opportunities, and some of it is very incremental, probably not a role for an ARPA–E. And second, there is a deep manufacturing process side, that gets to your point about cost.

One thing that DARPA has done an interesting job on, occasionally, over the years is looking at how to drive down manufacturing costs for defense products. It is a very sophisticated technology problem; it is a very sophisticated R&D problem. A lot of DARPA's work in bringing IT into the manufacturing process has had huge payoffs for other sectors as well. In order for a lot of the new technologies that we are going to need to compete, there is a manufacturing process task that we are going to have to go after, and this might be an interesting task, at least for breakthrough parts of that, for an ARPA–E as well.

So, I think there is a series of roles—as we begin to break down the jobs that we need to get done in this complex sector—I think there is a series of roles an ARPA–E could play.

Mr. DENNISTON. Congressman, could I try and answer? Your question was is it sensible public policy to put a price on carbon, and I am going to give you an answer in one simple declarative sentence. Emphatically, yes.

I believe that is the single most important thing that Congress can do. Research is really important. We have got to do that, but we have a free externality now that needs to be changed. I think I gave you two sentences. If I could add one more comment, going back to your prior question on nuclear.

If you look back over 50 years, and you add up the federal research funding of nuclear plus renewables, it is a large sum. Of that sum, nuclear has received 96 percent of the total. So, I believe it is time to level the playing field, and give some of these renewables a shot at the market.

Dr. VAN ATTA. If I can, just one quick point. You can talk about the market forces, technologies available, these market forces. That was true in 1958, '59, '60, in computers. There was a market force, and it was called IBM. It controlled the technology. It controlled the marketplace, in much the same way as the large energy companies, the large power producers, et cetera, do in the energy field today, perhaps not quite to the same extent, but largely, in terms of controlling what is out there.

DARPA created the alternative capabilities and technology that allowed others to enter into the marketplace, and also provided some mechanisms by which those technologies actually got out into the field. Through various internal procurement aspects, the government is a major consumer of energy. The government sets regu-

lations on energy. The government procures energy systems. If those new ideas are coming forward, and have major impact, but perhaps need to be buffered over time, in terms of cost and risk, the government can play some very successful roles in spurring the adaptation of those technologies and implementation.

And I think there are some lessons learned as to how DARPA did that in certain areas, and I think there are some other public policy examples we have that can be useful in that as well.

HOMELAND SECURITY ADVANCED RESEARCH PROJECTS AGENCY (HSARPA)

Chairwoman GIFFORDS. Thank you. This question is mostly directed to Mr. Bonvillian and also Dr. Van Atta, but certainly, feel free to comment if you have some thoughts on this.

Mr. Bonvillian, you were instrumental in developing the Homeland Security ARPA model, and looking at your written testimony, the program has not been, by and large, very successful. So, I am curious what we can learn in terms of not having successes there in Homeland Security. What sort of lessons can be learned, and how are we going to possibly avoid these problems with the ARPA–E model?

Mr. BONVILLIAN. You know, this committee, the Science Committee, played a very central role in trying to tackle the whole science and technology mission of Homeland Security, including standing up an HSARPA model. So, when I was working on the Hill, I worked very, very closely with this committee's staff. They were equally involved.

The Committee provided HSARPA, I thought and still believe, a strong and flexible authorization that was modeled on DARPA's strengths. But HSARPA was never adequately utilized or implemented, and it really exists now as a shell within a much larger organization, with a very minimal budget. And while a very talented initial staff, including a number of very talented people from DARPA itself, were hired to organize the entity, it was a significant period of time, over a year, before HSARPA obtained a leader. Unfortunately, because of illness, he was not able to stay in that entity for a lengthy period of time.

So, there was an initial leadership gap problem. I think there is a series of lessons here that we can learn. First, an innovation culture is critical to success. I think the HSARPA entity had the team to be able to do that innovation initially, but the culture of the entity—the overall DHS Science and Technology Directorate—that it got stood up in was not prepared to accept this. It was, in effect, being rejected as a foreign body.

So, having support from the agencies and/or overall entity in which this ARPA–E will be stood up becomes crucial. Relationships with the Department of Energy, if it is stood up at DOE, become absolutely vital. This has got to be something DOE wants to do. Otherwise, it is just not going to work. And that became a problem, even though the whole S&T Directorate was also new, that became a problem within Homeland Security.

ARPA–E is going to need its own budget, and the ability to control it. HSARPA did not have that power; its budget was controlled from above. It never had the authority to even make R&D deci-

sions. All of those had to go through a constant approval process. So, it was never allowed the autonomy that we have talked about as a necessity. It never had an island to be creative. So, that needs to be ensured, and control over its own budget is an absolute necessity, and it has got to be a sizable enough budget to make a difference.

Technical talent of great skill is vital here, but you also need people with experience in the federal R&D system that are going to know how to relate to the other bureaucracies, who are going to know people there, know how they are organized, know what their cultures are, to be able to make those connections work. I think that is another lesson to draw from this HSARPA experience.

And finally, you need to decide on the fundamental mission. One of the issues within the DHS Science and Technology Directorate was that there was a lot of short-term technology available that needed to be stood up quickly, given the threat to the country. And HSARPA can play a role in that, of course, but its fundamental mission is much more on the breakthrough side, the left-right model that we talked about earlier.

If you try to mix the two missions together, short and long range R&D, you run into difficulties. And the shorter-term mission, which is frankly a more expensive mission often, because you are standing up technologies, tends to become a bill-payer for the longer-term mission, because the deadlines are not as real. So, HSARPA got raided, in a way, to stand up a lot of the shorter-term problems. So, decide early on what the mission is, and don't try to mix it, if you try to stand up an ARPA–E.

Chairwoman GIFFORDS. Thank you. Dr. Van Atta.

Dr. VAN ATTA. Well, I agree that Bill has pretty much put his finger on it. First of all, the imperative of the near-term overwhelmed the ideas of HSARPA, the long-term, after 9/11, get things out there, do things quickly. Whatever we had, go find it, so it was very, very short-term, almost commercial, off the shelf, paint it a different color and get it out there.

That swept away any of the longer-term notions, and put them on the back burner, constantly kept moving them back. The lack of budget, the lack of autonomy, the lack of independence, all the things we talked about that made DARPA DARPA weren't part of HSARPA. So, I think we can learn pretty much that if you don't do it right, you are going to get it wrong.

Chairwoman GIFFORDS. Thank you. Let me turn to Ms. Biggert.

ARPA–E REPORTING STRUCTURE

Ms. BIGGERT. Thank you very much, Madam Chairman.

Thank you all for being here. I know that I have discussed this issue, and I don't know if any of you were at any of the hearings that we had last year, where we picked this up, but one of the things I would like to know is if you have all read the recommendations on ARPA–E included in the National Academies' *Gathering Storm* report. And I would like everybody to say yes or no, and everybody is waving yes.

Okay. And if so, do you believe their recommendation is clear as to the exact function, role, and structure of

ARPA–E, or do you believe it leaves a lot of questions unanswered? We will start. Just—Mr. Bonvillian.

Mr. BONVILLIAN. Congresswoman, they did not provide a lot of detail in the *Gathering Storm* report. They did not lay out a framework. They laid out an idea. They laid out a concept. They identified what they felt was an institutional gap in the array of institutions that we have at DOE. And I don't want to be critical of DOE here. I mean, there are great things going on in the Office of Science. There are great things going on in our federal laboratories.

The point I would make, though, is that this particular translational role has not been tasked to DOE, and the institutional array to tackle it just hasn't been set up at this time.

Ms. BIGGERT. Okay.

Mr. BONVILLIAN. And then, the question becomes whether or not you can use existing institutions at DOE to do this, and I would argue no, you probably want to create this thing, if that is a role that you want to make.

Ms. BIGGERT. Okay, Mr. Denniston.

Mr. DENNISTON. No. I don't think that the *Gathering Storm* report provided implementation details. I view it as an idea. So, they don't talk specifically about which technologies, fossil, nuclear, renewable. They don't talk about stage of research, should it be translational, is it basic, is it applied? They don't talk about the organizational details, much of which you have heard today.

They do talk about funding levels, which are exactly what you have in the draft ARPA–E, but they don't explain where those numbers came from, and so, I think there is a lot—while the fundamental idea is sound, an awful lot of the implementation details are absent, and should be addressed in ARPA–E.

Ms. BIGGERT. Dr. Forrest.

Dr. FORREST. I agree with the previous two speakers, in that it is more of a schematic diagram of what this agency would look like. One of the things that it does comment on, though, is that the agency should report to the Under Secretary of Science, and I do not believe that that is the best location for this reporting structure. It should go directly to the Secretary of Energy.

The other thing, I do believe that although it is schematic to be discussing specific funding levels, probably which are rapidly being swept aside by current events and so on, is probably something that the Committee and the Congress should discuss as a whole, but I would look at those recommendations as a starting point, but not an ending point for what we need to do here.

Ms. BIGGERT. Dr. Van Atta.

Dr. VAN ATTA. Yeah, I pretty much agree, that what they presented there was a generic approach, one looking for a fundamental alternative. Norm Augustine is very familiar with DARPA, being on the Defense Science Board, having worked, you know, as Chairman of Lockheed Martin, and in fact, being the head of the Army Science Technology, back when he worked with the Office of Secretary of Defense.

So, he knew the effectiveness and the impact that had for security and defense, and so, I think they were looking at this as a model, but not to be explicitly, they didn't have the explicit implementation details.

ARPA–E STUDY

Ms. BIGGERT. Okay. Thank you. In a bill that we passed at the end of last year, H.R. 6203, we had a suggestion for a study, an ARPA–E study that would be conducted by—well, the Secretary of Department of Energy would enter into an arrangement with the National Academies of Sciences to conduct a detailed study, and make further recommendations, and obviously, it is too late for that now, as far as that bill, because it passed the House, but not the Senate.

But do you think—I am concerned about setting up a completely different agency before we have answered a lot of these questions that were put forward. As you just mentioned, there were unanswered questions before we set up a completely new agency, and there are about five questions. You know, to determine what everybody does now, so to know what would be the focus of the new agency, and how, to the extent that DARPA would be used as the, whether it should be used as, whether it is the appropriate model, how research and development sponsored by ARPA would differ from that that is done by the National Labs, or sponsored by the Office of Science, or Office of Energy Efficiency, and should industry or National Laboratories be recipients of the ARPA–E grants, which I think are all questions that really need to be answered before this happens.

Dr. FORREST. I would like to answer a couple of those questions. In my formal remarks, where I did mention that the flexibility of DARPA came from the fact that it really does not provide substantial funding to the DOD labs, which is the equivalent.

The National Labs simply are not organized to be a functional change agent within our country. I think a lot of the questions that you asked are very important, but I do think we know many of the answers. I think we do know what the goal of the Labs are. We do know, for example, what the basic mission of the basic energy sciences, for example, is funding. And I do believe that given the scale of the problem, there is a huge, unmet need in the center, and that is this translation between idea and moving to market. And this is what has not been served traditionally, we know this quite well, by the Department of Energy, and we really have to move on from that point, because of the national strategic need for this, and also, for the environmental challenge that we are facing.

Ms. BIGGERT. I don't think that is all, you know, all of the question, because it is, you know, it can be private, whatever. Let me just say that, a couple of things I hear. I think that most of you seem, I think, it makes it sound like the National Labs don't do anything, and to me, it was always their focus, was to be the innovation, to do the basic research that is going to lead them to the transitional, to lead to the marketplace. And I think the difference between DARPA and ARPA–E is that when DARPA develops something, it is developed, but it has the demand. I mean, they—it has the demand for it, because we have the military, which is then going to receive the product that is developed.

What happens in the sciences is we don't know what the demand will be, and you are talking about fossil fuels. If they are not, you know, while we are using those, we haven't been able to convince

the—or find the demand that is going to do away with those. For example, let us take a hybrid car. Right now, we are seeing the higher prices of gasoline, so people are going out and buying more hybrid cars, which is really good, but if we have offered an incentive to, because the price is higher, so what we have to do is to create the—everybody is going to want to buy a hybrid car, and they are not going to want to use just one that has gasoline in it.

With the military, they are going to determine that this is the product that is going to be used in lieu of something else that isn't as good, and that is what worries me. You set this up, and say okay, we are going to find the innovation, and we have to, to complete——

Mr. DENNISTON. Can I——

Ms. BIGGERT. Yes, sir.

Mr. DENNISTON. Can I try a shot at that, Congresswoman? First is on the question of a study. I wouldn't do a study. I think this subcommittee has the facts and the expertise to be able to decide those details. A study delays implementation, which I would be very much opposed to.

On your question, on the distinction that you draw between DARPA and ARPA–E, my belief is that is a distinction without a difference, and I think my view is that we are currently today seeing a Moore's Law effect in the renewable energy field, where wind power, the price of wind power has declined by an order of magnitude in the past 20 years. Solar power, by 60 percent in the same period of time. Biofuels are twice as efficient now as they were in the '80s, and that is before we put a lot of resources, private industry and federal, on it. I can assure you that this Moore's Law, the slope of the curve will accelerate.

And the objective of this is to end up with renewable sources of energy that are price-advantaged over the incumbent sources, and the sooner we do that, the sooner that we will relieve ourselves of the three crises: energy dependence, American competitiveness, and climate change.

I was in China over the summer, and I had lunch with the General Director of their Ministry of Science and Technology, on the subject of energy research. They are doing an enormous amount. He didn't tell me the amount that they are funding, but pointed me in different directions around the country. They are putting a lot of resource on this. I was in Europe last month, visiting with governmental officials. There is a race to lead the next industrial revolution. In my opinion, it will be around energy, and if America doesn't lead that race, then we will pay the consequences, in terms of standard of living, jobs, and prosperity in this country. This is urgent, it is a crisis, we need to get going, in my view.

Ms. BIGGERT. I think we would all agree with you, but I would add to that that we have to really focus in on nuclear energy and the recycling of the waste, and I think that we need to get going on that, and I worry that some of these other things might take, you know, because it is going to be the cost, but in the long-term, it is going to lower, you know, because it will come down once we have developed enough of the reactors and enough of the recycling.

Dr. FORREST. If I could just, if I may, just wheel out one statistic. Germany has been working very hard on solar. In about five years,

they anticipate that more energy in Germany will be produced by solar power than by nuclear power. The cost curves that are driving solar today are extraordinarily aggressive, and if we stay on this track—by the way, there are some very large American suppliers of that German solar energy, which is good news. But I think that there are numerous things—there is no silver bullet here in finding a single energy solution, but we really do have to work on renewables, because that is where the future of this technology is going.

Ms. BIGGERT. Yeah. And I think what you are saying is absolutely true, but I don't know if there is just one silver bullet, like ARPA–E, that is going to create that. And I know I am way over my time, Madam Chairman. If I might just go back. I hope Mr. Denniston does not think it would be worthwhile for NAS to answer some of these unanswered questions, or come to some kind of consensus to, you know, to find out what their recommendations are.

Mr. Bonvillian—how do you—do you think that NAS should do a study, or there should be any answers?

Mr. BONVILLIAN. Congresswoman, I think we know a tremendous amount about the DARPA model, and we understand what that is. And I think that there is a fair amount of understanding, including, in some circles at DOE, that this translational role is not there. It is not within the current DOE institutional array. It is not anyone's fault, there just happens to be a gap.

I think the critical decisions is are we going to fill that institutional gap, and are we going to allocate the resources necessary to fill that gap? If you decide to fill the gap, there is a variety of solutions, inside DOE, or outside DOE, as a component within or as an entity outside some existing entity. There is a variety of solutions there, but the real decision is are we going to fill that institutional gap in some way, and then, are we going to put the resources into this, in order to enable it to operate at scale, to begin to stand up the array, or the portfolio, of technology options we are going to have to have at. I think those are probably the crucial questions.

Ms. BIGGERT. Thank you. Dr. Forrest.

Dr. FORREST. I think I have commented enough on that.

Ms. BIGGERT. All right. And Dr. Van Atta.

Dr. VAN ATTA. I am an analyst by trade, and so, doing studies is always a wonderful idea, except there is a time we have to stop doing studies. The fact of the matter is, is there is a well-defined issue and need here, and a potential mechanism. I have raised the questions in terms of the issue of commercialization, the issue of the role of the Labs, et cetera. All of these things are things that management direction from leadership can lay out in terms of these are things that we need to be concerned about.

How do you link to the National Labs, whether it is the major defense labs, or whether it is Argonne or Oak Ridge? They have great new technological capabilities there. How do those move from there into demonstration practices, in terms of proof-of-concept for application? An ARPA–E might be a mechanism where those ideas can be moved out of the lab. Because one of the problems is the Labs do work in the Labs. The question of how to get things out of the Labs, and from the Labs into other people's hands is some-

thing that we are all interested in finding better solutions for, and ARPA–E could provide a mechanism for that.

In terms of mechanisms, in terms of whether it should be nuclear, et cetera, that is part of a strategy. That strategy has to be set at the national level, and that is part of the strategy which is set by leadership. The roles of the different technological capabilities towards reaching those strategic goals have to be evaluated. I don't think a National Academy can make those determinations up front any more than anyone else can. That has to be part of an overall strategic develop.

Professor Sokoloff, for example, has presented this notion of the wedges. It is very clear that not any single one of these technological capabilities is going to solve the problem. My father spent his entire career at Lawrence in Berkeley and Livermore developing fusion energy technological capabilities. I can say that, you know, that is a crucial potential for the very, very long-term future, but we don't know what the breakthroughs are that will make that happen. Should some of those breakthroughs be identified as potentials, and ARPA–E might be a mechanism to test a couple of those out, or develop the underlying capabilities.

Ms. BIGGERT. Thank you very much.

Dr. VAN ATTA. When you have to be based upon ideas, rather than just substantive areas.

Ms. BIGGERT. Thank you. I yield back. Thank you.

RENEWABLE ENERGY TECHNOLOGY INDUSTRY

Chairwoman GIFFORDS. Heading back to an area that Mr. Denniston talked about, one of the goals of the ARPA–E project is to faster innovation of a new U.S. energy technology industry, and to create a new workforce built around this new sector, or greentech. But to the extent that this market has developed already, in terms of now we see that the Japanese, the Europeans, and also, the Chinese are starting to gain the lead.

Some questions I would hope the panel could answer. One, can ARPA–E ensure that the United States stays on the front end of technological innovation, and supports the domestic energy industry? Two, should ARPA–E have an explicit Buy America clause, or otherwise ensure that these technologies are manufactured and deployed in the United States first? Three, what kind of workforce do you all see developing around this new clean energy technology? And fourth, what levels of education and training are going to be required for this new workforce?

A lot of questions, but again, just the staying innovative, on top, the Buy America, the development around the clean energy technologies, and then, the training.

Mr. DENNISTON. I will be happy to take a shot and those, and I am sure my colleagues will have their own thoughts.

So, will ARPA–E ensure that the U.S. is on the leading edge and is the leader? There is no guarantee. I would look at the converse of that, which is if we don't have an ARPA–E or something like that, I think we have a very low probability of doing so, because as my fellow panelists have pointed out a number of times, there is no translational function being performed today, and we know that without that, we will struggle to come up with the break-

throughs. Others are doing that across the world. We are in a global race, so I think we need it to have a chance to stay at the front end.

In terms of Buy America, I don't even know what that means. Does that require that companies, U.S. companies, not—because the buyers of these technologies won't be energy companies, and so, if the U.S. Federal Government funds research that startup or mature companies roll out, do we make other consumers, businesses and consumers buy them? I don't think that is a good idea. I think you can create incentives, so I will tell you right now, in both Asia and in Europe, there are strong incentives to set up manufacturing there, tax incentives, you can do to Singapore and get a ten year tax holiday for setting up manufacturing operations there. That is what the U.S. is competing with to put manufacturing facilities in place. I don't think—you probably could mandate by statute that all Americans buy all American products, but that would be un-American, I think.

Your third question is what about the workforce. The workforce is, this will be a boon for technology and innovation, and what we saw happen over the past three decades, as the NIH budget quintupled, is enormous, topflight technical talent sprinting into the health care field, the research field, because that is where the money was. And that is what we will see happen also in the renewable energy field if there is significant funding, because the best and the brightest can look at that and say wow, this is a really interesting area, and I can get my projects funded. So, I think on the technical, scientific level, it is an excellent idea. If there are—there will be manufacturing as well, no doubt about it. How much is a function of public policy.

And your last question was on education and training, and I can tell you from visits that I have made, which I do frequently, to our top research institutions, academic research institutions, that there is enormous interest to pursue energy, because our best academic institutions see that as an area where they can make a difference, a growth area going forward, so I think those are your four questions.

Dr. FORREST. I would like to jump in, too, and talk as an educator, what is like, what is happening out there on the ground.

And I am a person who grew up in the Space Race, the generation of the Space Race, and Kennedy, President Kennedy at the time created a national challenge that struck and galvanized not just a generation of young people to go into science and technology, but a generation of young people's parents to encourage their children to go and to solve a national need.

I haven't seen in the interim a challenge that has arisen that has affected the psyche of young people beyond that which I now see now, with sustainability of the environment and energy independence. Energy institutes are starting to arise, some very formidable ones, at many universities, our university, the University of Michigan, has just established Michigan Memorial Phoenix Energy Institute, which is an antecedent, it is following on in the footsteps of our Atoms for Peace program, that was established at the end of the Second World War.

So, by putting more money into the research end of things, which ultimately creates jobs, you will find that there will be a large, emerging, and effective workforce that will assure U.S. competitiveness. Just establishment of an agency does not do that, but DARPA has had that effect, very much so, in establishing a generation or multiple generations of young people who have gone into the technologies that have been generated out of DARPA. And I believe that we are, today, reaping the benefits of those changes.

One last point is that if you look at American funding of alternative energies, and alternative energy research, over the last twenty years, Japan has been ahead of us. Over the last ten, Europe has been ahead of us. They have very rapidly increasing budgets in these areas. Ours is flat or declining in some areas.

So, I think that if you really talk about the long-term competitiveness of this Nation, which is coupled directly into our standard of living, this is the place we really have to draw the line, and make some commitments to, for the long-term.

Mr. BONVILLIAN. I wonder if I could add—I am sorry.

Chairwoman GIFFORDS. Well, we will start with Dr. Van Atta, and could you——

Mr. BONVILLIAN. Sure.

Dr. VAN ATTA. It is interesting, on the ARPA–E ensuring our leadership. A few months ago, I was over in Japan, at a Japan-U.S. climate change forum informal working group, and I explained, similar to what I did today here, the DARPA model, and how it worked, and how it might work in the energy area, and the Japanese all were very bright young technical people from METI, their economic and technology institute, were both jealous and astonished.

What a wonderful thing. We could never do that here. And basically, with the notion that that is something that gives us a fundamental advantage relative to them. They have other advantages, one of which is they are very, very aware of energy prices, and they are very, very aware of their environment.

As far as explicit Buy America, the world doesn't work that way. If you are going to make these technologies, and make them work, it has got to be global. It has got to have global impact, and we have to be the leaders in global technology. Finding ways of creating the best, so that the world comes to it for affordability and quality is what we have to do. Legislating it won't make it happen. It doesn't work in DOD, and it won't work here either.

As far as the workforce, we are talking about bioengineering, nanoengineering, materials, even old technologies like physics and chemistry, all are going to come to play here. They are going to regenerate and recreate whole new areas, and then, you are talking about product manufacturing. GE and windmills, who is going to make those solar cells of Dr. Forrest's? There are going to whole sets of technology leaders, technology producers, the same people who did the Intel thin film microcircuit technologies are going to be making his solar cells.

That is how we are going to generate a workforce, and you are right, education and training in science and technology, keeping that pipeline of young, fresh minds going is crucial. Having the ob-

jectives toward changing our society, in terms of our energy, our climate, will draw these students in.

Chairwoman GIFFORDS. Mr. Bonvillian.

Mr. BONVILLIAN. I just wanted to add a word on the workforce and your questions.

I was with an MIT professor this morning who teaches chemical engineering, who has done a tremendous amount of work on carbon capture and sequestration. He decided to turn his engineering design class over to these energy technological problems. He got an enrollment he couldn't believe, that he had never seen before, 80 students. He divided them into 20 different teams. He said they worked harder than he had ever seen students work before. When he came to the end of the semester, he said half the teams approached him, asking if they could continue working all summer on the energy problems. This doesn't happen a lot, and the level of interest and enthusiasm that is in this energy issue is so powerful. I am sure Steve has stories very much like this.

MIT has a campus-wide energy initiative. In some key ways, it was and is student-driven. There is a new energy club started a couple of years ago at MIT. They meet every two weeks. They often have 400 students at their bi-weekly meetings, which is unheard-of. It is by far the most active student activity. So, there is an incredible amount of talent that wants to go into this energy field and find ways into it.

We stimulated a generation of talent into the life sciences by the increases that we gave to NIH. That research funding put that talent in that field. Life science is a field where we have world dominance. This is a competitive sector that no one is close to, in biotechnology and pharmaceuticals. We can do the same thing here. Part of the story is in strengthening our research investments, because I think the talent is going to be there.

And let me just mention one other thing that DARPA has done over the years. As Dick pointed out, there have been many DARPAs, and there are issues now in some areas. But over the years, DARPA created a tradition of what it called "DARPA hard" problems. Really hard problems. And the nature of those tough problems just drew talent, sucked talent into them, and produced incredible technology over the years. And one of the interesting things about an ARPA–E model is that you can create, if you are working on a breakthrough, revolutionary technology model, you can create those DARPA hard problems, and draw a whole generation of talent in to attack them. And these are the challenges of our time.

Chairwoman GIFFORDS. Thank you. Just to clarify, in terms of the Buy America label, like I say, one of the goals of ARPA–E is to focus on the U.S. technology industry, so the idea would be that these technologies are first manufactured and deployed here in the United States, over giving preference to another nation. So, and again, I would have to look at the language of the bill, but I just want to make sure that you know, we are clear, in terms of meeting the goals, or not meeting those goals.

Mr. DENNISTON. I am still struggling with the concept. I think if ARPA–E succeeds in finding breakthroughs, and the biggest problem is they can't produce enough to fill market demand, that

would be a really good outcome. Okay. That would be a fabulous outcome, and maybe at that point, Congress can look at allocating that, but that would be the best success that we could hope for, is that we find a breakthrough that the entire world is rushing to grab onto and deploy, because it offers huge advantages over fossil and nuclear and everything else that is out there. I think that would be a very happy circumstance for us to see.

Dr. VAN ATTA. I will go so far as to say that if you look at how DARPA succeeded in Silicon Valley, the times have changed. If you fund the generation of ideas, and the development of the prototypes within the U.S., through U.S. universities with U.S. companies being involved, the beginnings of that manufacturing and production will happen in the U.S. Can you legislate that, and say that is the way it has to be for every one? I think that would be too narrow. Can you say that is the expectations, when you are funding people? I think you can say that you expect to see that that research will lead to development of production facilities initially in the U.S. If you insist that they stay in the U.S., you will get what happens with the Motorolas, et cetera, of this world, when they say if you are trying to squeeze me down here, I will go somewhere else.

And you have to remember, also, that there are lots of incentives being paid out in China and elsewhere, to bring people there. The Microsoft Research Center in Beijing has lots of incentives to be there, and to develop Chinese-based researchers, because of our export control laws, so I would be careful that we don't create the incentives for people to be elsewhere, by creating things like Buy America, and they say well, in that case, we will produce our research somewhere else.

Chairwoman GIFFORDS. And you know, this question stemmed from suggestions about what should be in the bill. It is not currently written in, but I am glad to have your feedback on that.

Ms. Biggert, please.

ARPA–E PROGRAM STRUCTURE

Ms. BIGGERT. Thank you. I am certainly open to this concept, and I agree with everything that you are saying, how we need to compete, and we need the research, and we need it done. I just worry about actually putting it into a single box, and saying this is the way it is going to be done. And the reason I say that is I have to tell you my DARPA story, and I had a group come in to see me, and they were scientists who were, had spun off from Argonne, so they were looking how they were going to get this, get their product to market. And it was a product that would, the military would be the focus.

So, they applied to DARPA, and they, and they developed, produced inexpensive, high quality titanium, which could be rolled out, and it was something that the Department of Defense was searching for. They were turned down, so they came to my office, and we started to work on it, yet I got some funding for them to further develop. You know, you are talking about where a company is in the development, but they haven't been able to produce enough, to get it to work on a high scale. So, it was obvious that this worked, and finally got the Department of Energy, or Department of De-

fense, to take a look at it again, and it was exactly what they were looking for, that they had to have, to produce a product by 2008. So, they are now producing it for them, and what worries me is here was a product that was right there in front of their faces, and they didn't see it. It didn't, you know, at that time. So, they, the scientists got private capital, built a plant, and demonstrated that it worked, and then DARPA decided to, and this was high risk, so the story ends that both DOE and Boeing, the largest consumer of titanium in the world, joined the Army to discuss this in my office, and suddenly, it just took off.

And that is why I worry, and here is the homeland security that hasn't worked. I mean, we—a couple weeks ago, I had the Secretary of Energy out at my district, again, to look at some of the companies that are in the district, and how they are transitioning from the, you know, the early development, they are all spin-offs from Argonne, and they are working to put their products out, and they are going to be in high demand. We have got nanotechnology, we have got, you know, all kinds of companies that are able to produce these now.

I don't want to stifle any, you know, of that type of—if this would be a place where everybody is going to come to, and it is going to——

Dr. FORREST. I can't comment directly on the case that you are alluding to, but I would like to make two distinctions first of all, or two statements. One is we don't have a system in any agency or part of government which is perfect. Mistakes do get made. But I don't think that anyone here is also advocating that all energy funding get filtered through an ARPA–E. There is still tremendous amounts of funding that we would anticipate would continue to flow through the same sources as always, through the Office of Science, to the National Labs, that would fund basic energy research and so on.

ARPA–E is filling a gap, and that is all it is doing, and that gap is the translational gap. The good news about this country is we have a diversity of solutions to any problem, and so the one that you allude to, it seems like the problem was solved in any event. We don't expect perfection from ARPA–E, but we do all recognize, I believe, that there is this very critical function that it can fill, which is currently unmet as a need.

Dr. VAN ATTA. I can comment on this, in terms of I used to run some of the programs at the Pentagon dealing with some of the Title III, Defense Production Act, which dealt with a fair amount of the materials areas. I think both the DOD and the government in general needs to have a little more focus on the fundamental, underlying, crucial needs for advanced materials and alternative materials, including metals. Metals tend to get kind of shortshrifted. They seem old, but there is lots of new and interesting things, as we are getting more and more sophisticated in some of our technologies.

On the other hand, there is an important point here, which is this diversity of alternatives that this country has, that you know, blows the other guys away. They can't understand that we have so many mechanisms, the Advanced Technology Program in Commerce, which is now, I guess, has been modified and changed. We

have mechanisms that allow people to find, that are ways of getting that technology in.

It is important that one not presume that a single agency is going to solve all the problems. DARPA doesn't solve all of DOD's problems. That is why we have a whole range of other systems within the services, et cetera. And you can't expect or think that this agency is going to provide the complete one stop shop across all, nor should it think itself as that. Otherwise—and we are going to have a competition for ideas and competition for resources here, and I know there is a concern that this will mean that the prospects are that some other existing organization, whether it is a defense lab, or some other organization, a DOE lab, or the S&T program, is going to say well, gee, if this thing comes alive, it is going to, some prospects will take money from us. And the answer is the competition amongst organizations to fill our national needs is a good thing. And just because something new and different is going to hit the street doesn't mean that we should suddenly say well, okay, wait a minute, we have got this program, that program, they are going to be at risk. They have to compete on the basis of merit, what they are doing for the country, and meeting their needs.

And if we have a fundamental unmet need here, which I think we have tried to demonstrate here, that has to get on the table and compete with those other ideas.

ENERGY RESEARCH FUNDING

Mr. DENNISTON. There has been a suggestion a couple times in this hearing of a concern that increased federal research funding for energy would crowd out private alternatives, and I disagree with that suggestion, and I will tell you why, for two reasons.

The first is the current level of private investment in energy research is very, very, very small, compared to the industries that we are talking about. So, the annual revenue of the energy and transportation industries in the aggregate is $1.8 trillion. The venture capital industry last year invested, depending on who you ask, $1 or $2 billion. Some larger companies invest some, but it doesn't add up to nearly one tenth of one percent of industry revenues, and if you show me an industry that is investing one tenth of one percent in research and development, I can tell you that is an industry that is not investing for the future.

We need more research funding. Historically, the government has been an integral part of that, and so, my suggestion is we should let the best idea win. If that best idea comes out of ARPA–E or some other federal research funding, as it did in the health care field for the past 30 years, that will get transferred over to private industry, and we will have a very successful American company, and it is much better that that idea come from the U.S. than from a foreign country, and by increasing federal energy research funding, we increase the probability that America leads the next industrial revolution.

Ms. BIGGERT. Maybe it should be the technology revolution, but——

Mr. DENNISTON. Sure.

Dr. VAN ATTA. I wanted to make a point on the private investment. I did a study a bit ago, as I do do studies, on the role of ven-

ture capital in DOD, and it was interesting. I interviewed several people, including Kleiner Perkins and some others, and one of the things that was interesting is I asked where do you go as venture capitalists think of the next ideas where things would come from. They say we look at DARPA. Where are they going?

So, the amount of money that goes into areas of interest has a lot to do with the kind of money that government is putting in that shows interest and shows direction. SEMATECH helped create government, industry investments in semiconductor manufacturing in this country, that the Intels, the IBMs, the Motorolas and all, built on. So, the interrelationship, that partnership between the government and industry, is crucial. And we have to realize that that is now happening around the world, so we are in a competitive race when you see what other governments are doing to encourage that R&D and that technology development. And that is based upon their interest in achieving their competitive status versus us. And we have to realize this is now a hypercompetitive world in these areas, and if we want to rest on our laurels, we are going to have to be worried where we are going to be in 15, 20 years.

Ms. BIGGERT. Well, 50 percent of GDP in the last 50 years is the result of research and development, so we have got to continue with this. Thank you very much. I yield back.

RECOUPMENT

Chairwoman GIFFORDS. Thank you. In Chairman Gordon's absence, I would like the panel to address this question that he talked about on terms of recouping, recoupment of dollars. There is a provision in the bill, it calls for the Secretary to develop procedures to recoup the federal share of commercially successful projects under ARPA–E, and gives the Secretary authority to waive the provision.

So, I am curious if members of our panel think that is a good idea or not a good idea, and why.

Mr. BONVILLIAN. Maybe I can start off. I am concerned about this provision. Essentially, you want to encourage new technologies to be stood up, but you are putting on a clause on them that essentially allows recapture up to a 20 year period, and I think that is a burden that we should not impose on new ideas and new technologies.

Somebody is going to have to pay that bill, and the R&D investment is going to be discounted on day one, as that technology is stood up. Everybody is going to know that it is going to have to get repaid at some future date, and it is going to be a burden on the standup process. We have not imposed recoupment on any other federal R&D. I think, frankly, it has been a very smart strategy on our part. We capture the cost of the great new technologies we stand up through the R&D process through the tax system. We stand up small companies, they become successful, we tax them at a pretty tough corporate rate. That is the way the government operates. We don't tax the new technologies. We don't want to discourage new technologies. Let us just recoup it through the tax system at a later stage.

So, I am concerned about this. Now, in my view, the immediate problem that we have is adequate revenue to stand this new entity

up at the beginning. A recoupment clause is not going to help solve that problem. It is a much later stage recovery problem.

Now, there will, at some point, I trust, in the next few years, be some kind of cap and trade macro pricing system that will be imposed on various energy-dependent economic sectors in the United States. That cap and trade proposal is going to raise very significant income through the initial auctions, and auctions continue on an annualized basis in the bills that are currently in front of the Congress.

Typically, the government's recovery at the initial auction stage is comparatively low. You want to give people time to transition, but that recovery goes up over a period of time. These allocations are going to generate tens of billions of dollars, and we will be making a foolish mistake if we don't spend a lot of that cap and trade allocation money on the new technologies and the innovation system that we are going to need.

So, I think that what we have here is an interim problem, between now and then, to stand ARPA–E up with adequate revenues. There also may be some other revenues in the oil and gas royalties area, that you could look at, which I know some of the Committee has taken a look at already. That seems to be a possibility. You may also want to consider an initial one year sizable grant here.

The country is going to have to spend a lot more money on our energy R&D. Otherwise, we are going to cede the energy innovation territory. And therefore, I know these investments are coming. I worry that a recoupment clause, by taxing technology, as opposed to successful companies, is a problematic way to go.

Dr. FORREST. I would also like to chime in on that one. I have been fortunate enough to have been a partner in several companies that started up. One of the companies was financed almost entirely through the Small Business Innovation Research Program. It is called Sensors Unlimited. Over the years, it brought in probably a few million dollars worth of SBIR money at the height of the Internet bubble, it sold for $700 million. The return to the Federal Government from that sale was—the CEO of that company calculated something like 20 to one, compared to the investment.

To have unfettered investment is very important. I would also like to say that I have seen these type of clauses in state law. Very often, they get tangled up in the agreements that companies already have with their primary investors, because there is payback clauses there, too. And so, what happens is the government now becomes a competitor against the private sector when it does this sort of thing, and it is very, I think, detrimental. Many grants like that from the state that I am in today have come under question, and have been turned back, and have not been accepted. I think this is a damper on real innovation. The Federal Government has been an excellent partner in driving innovation, understanding that by creating prosperity, it gets all the returns it needs, and to try to do this in a micro-way with a specific program, I think, has a detrimental effect, a dampening effect.

Mr. DENNISTON. I would echo Dr. Forrest's comments. I urge the Committee to pass a bill with significant increased funding levels. I know this is hard, a high degree of difficulty, but significant in-

crease in funding levels and no recoupment. You will see my comments in my written remarks.

I pity the ARPA–E Director with a recoupment clause, because now, there are two missions that stand in conflict. The first is to race technologies and solutions to the market, but the second is to do it with ankle weights on, and the recoupment clause is an ankle weight, because it requires negotiation with universities, with private industry. We have seen this movie before. It will slow the process down, so fundamentally, I think the Subcommittee has to decide whether to rank order priorities. Is the top priority to solve the problems, climate change, energy dependence, American competitiveness? Or is it to make this ARPA–E revenue-neutral? And for me, I have to express some frustration as an American, a voter, a taxpayer, that we find ourselves in a budget predicament where we are faced with a crisis, and we can't find budget for it. It is tremendously frustrating. That is a different topic for a different day. I agree with Mr. Bonvillian's comment that if ARPA–E succeeds, and we create breakthrough technologies, the Federal Treasury will be repaid many times over, in the form of income tax and payroll tax revenue. And if you want to recoup, then earmark those tax dollars, send them back to ARPA–E. That is the way to repay ARPA–E without putting ankle weights on from the get-go.

Dr. VAN ATTA. There is quite a bit more complication to this, as well. I agree with the comments that were made up to this point.

Who is going to pay that recoupment? Is it going to be Google? Is it going to be Cisco? Is it going to be Sun Microsystems? For many of the things that people are using, that were funded by DARPA, the first guys who got the money weren't the guys who succeeded. It was the guys after that, or the guys who built on that, or the guys who spun off of that. You can't track that. You can't evaluate that. There are a few. There are a few. If you go to QUALCOMM and Irwin Jacobs, he will tell you, I got my money from building up this TMA, it came from DARPA, working on a Defense problem, working with the Defense Department, and you know that QUALCOMM is paying the government back handsomely, in terms of its revenues and all that it is making today.

The crucial problem here is the recoupment assumes that there is a linear relationship between the dollars in and the results out. It is not linear, in terms of the dollars, and you have, you know, the one percent of the guys who succeeded makes you a billion dollars, but those guys may not have been the guys who got the original money. In fact, finding that and tracking that, there will be a lot of deniability here. Well, yeah, DARPA was over there somewhere, but I forgot all about them.

So, you have to be, I don't see how that works.

FOSTERING AN INNOVATIVE CULTURE

Chairwoman GIFFORDS. A couple final questions. In terms of, and something that all of you talked about, the independence of ARPA–E, how do we actually ensure that, and what have we learned from even the Congressional pressures that DARPA has experienced over time? How has DARPA insulated itself, and how, possibly, can we write into the bill that ARPA–E is kept really, truly independent?

Dr. VAN ATTA. Let me speak to that first, because I have actually addressed that issue a couple of times. You can't legislate independence. You have to raise the expectations that it will be independent, but you have an oversight role in Congress. So, you have, you know, there is a fundamental oversight role in terms of the budget, and in terms of expectations. You can state that the organization should be independent of specific and identified entities within the Departments through the management structure.

You can't guarantee that the bureaucracy will leave it alone. HSARPA is a great example of that. But I do think that you can manage it, and you can evaluate it, based upon the degree to which it has demonstrated results. The basic way that DARPA has managed to keep itself at least less prone to earmarks than other organizations is it can demonstrate that what it is already doing is so impactful and so necessary that they have been able to convince the Congress and the staffs that you shouldn't start throwing more stuff at it and diverting it, though there have been some very big earmarks put on by Congress that went into DARPA, including SEMATECH. So, it is not that it has been completely independent, but it hasn't been completely dependent, either.

The other issue is it doesn't come back and ask Congress to help it with money. It puts its program out there, and says this is what we want to do, and it is not hurting for money, so it keeps saying put more things in there. I think having a definitive, well laid out charter and mission, and permission to implement that, is the best way of doing that. It is very hard to legislate that, except to set the expectations of the independence.

Chairwoman GIFFORDS. Mr. Bonvillian.

Mr. BONVILLIAN. One model, which the Committee, I know, has been thinking about, is the wholly owned government corporation model, and you know, as we have all discussed for innovation entities in the business of standing up new technologies, a very successful model has been to put them on a protective island that is comparatively free from contending bureaucracies.

One way to do that is through a wholly owned government corporation. There are some——

Chairwoman GIFFORDS. I am sorry, Mr. Bonvillian. The mike cut out. What was that again?

Mr. BONVILLIAN. One way to do that is to create the entity within a wholly owned government corporation. Locating an ARPA–E in a corporation would assure it significant hiring flexibility, competitive salary structures, a certain freedom from Congressional earmarking interference, which, let us face it, will be an issue. And a corporation model can move it out of slower moving government bureaucratic procedures. So, there is significant advantage here. Some of these issues, you can fix in a statutory structure, including the contracting flexibility, and some of the employment hiring speed issues, but the corporation is an easier model for the standup process.

Now, there is a big issue here with a government corporation, which is that you have to have the bridge back to leadership. If a wholly owned government corporation is facing tough contending interests with political power, and let us face it, we have that in the energy field in spades, it is difficult for the corporation to main-

tain its independence, and to assure its ongoing viability, and particularly, to obtain ongoing funding. There may be battles about this an ongoing basis.

So, there are advantages to the corporation model. The way in which you make the model work, and it is not simple, is to make sure there is a very strong bridge back to political leadership that is prepared to have a stake in the corporate entity, understand it, back its research efforts, and provide it a certain kind of political screen and protection in the process.

Getting that balance right will be crucial. Otherwise, you are just going to have an island out there. But I do toss that out, throw that out to you, as a possible model that you may want to consider. You can do many of the same things within DOE. In other words, this is not an either/or option. You can create an island-bridge within DOE as well, but I think you should at least explore the wholly owned government corporation.

Dr. VAN ATTA. I would like to add a little bit more, Bill, to what you just said, because——

Chairwoman GIFFORDS. And Dr. Van Atta, can you also take into consideration whether or not there should be a written mission, because that is part of it as well, that we need to be looking at?

Dr. VAN ATTA. Yeah, I would say first of all, the fact that DARPA does report to the highest level, the Secretary of Defense, though administratively, that has linked it more to the Office of Acquisition, Technology, and Logistics. It is—the DARPA Director still reports to the Secretary of Defense, and his mission, if you will, if you go to the mission, is to achieve the goals of the Secretary, as related to the goals of the President.

It is not to meet service goals. It is not to meet individual goals of a particular sub-organization. And I think the mission, relative to sustaining U.S. leadership in energy technologies for both security and for climate change is a fundamental issue that should be the issue, the mission of this organization, and it should report to that mission, at the highest level. And it is at that highest level, not through all these other mechanisms and bureaucracies, subtiers, et cetera, that you maintain that independence. Keep it out of the bureaucratic strains, bureaucratic structures, as we said. HSARPA failed because it was part of, embedded in, and it had to report budgetarily through all those other mechanisms. While DARPA informs the DDR&E about its budget, it sets its own budget, in terms of how it allocates its dollars. It doesn't have to get approval from anybody as to how it allocates those dollars. That is crucial, and that is something which is set, not by legislation. It is set by administrative expectations within the organization, in terms of ensuring its independence, and the Secretary protects that.

FUNDING

Chairwoman GIFFORDS. My final question, I know we have kept you here for a couple of hours, but this is, I think, really the meat of it, the *Gathering Storm* report calls for the ARPA–E to authorize $300 million for the first year, and then quickly escalate up to $1 billion within five years.

H.R. 364 currently has a similar funding profile, but some suggest that the only way a high cost, risk-tolerant program like ARPA–E will be successful is if it is dedicated funding of some kind, therefore would not be subject to annual appropriations or other political or perhaps financial pressures or resource fluctuations that might stifle this sort of innovation.

So, I am curious whether or not this level of investment prescribed in H.R. 364 matches the magnitude of the challenges that we have talked about, and whoever wants to start.

Mr. DENNISTON. I will repeat what I said before, which is I think it is dangerously deficient. I think if you look at, again, the scope of the crises that we face, the scale of these industries, energy and transportation, $300 million pursuing change, well, ARPA–E, the current draft of ARPA–E says first year, $300 million, going up to $915 million in 2012. It is to go to fossil, nuclear, renewable. It is at all stages of energy research, basic, demonstration, and by the way, it is recoupable.

It doesn't—when you put all those factors across what the statute is proposing, my fear is it is not going to do very much at all. It is $300 million on a $1.8 trillion industry, is a rounding error. And we just have to do better if we want to place solving our crises, our energy crises as a top national priority. I hope we can do that.

Dr. FORREST. Let me just give you a little perspective. That builds on that $2 trillion number. If this were a business now, John will know more about this than I do, but most high tech businesses, technology businesses, or businesses that are really involved in the next generation of whatever product they are making, typically about five to 10 percent gets ploughed back into R&D. So, you can assume that that $1 trillion is bringing in about $100 billion of money to make change.

But unfortunately, it is really to embed, most of that money is coming in through the oil industry, so it is being invested to make sure that we have oil into the future from whatever source. So, if we are going to counter that with renewables for all the reasons that we have talked about today, we have to at least get on the map, and while there is always a start-up problem, how do you spend money wisely, you can't just put a lot of money on the table instantaneously, but that has to be a phase-in to something that really is equal to the problem, and I believe, like John does, that $1 billion is just woefully underfunded.

Mr. BONVILLIAN. So, I get a shot at it? I know the budget problems that the Congress faces, and they are painful, and how do you find $300 million, and persuade the appropriators to allocate it, much less $1 billion. These are DARPA-sized problems. DARPA is a $3 billion agency, right? If anything, these energy problems are more dramatic, in some ways, than what DARPA faces. How are you going to pull that off?

As I said before, I do think that there is a reasonable prospect over time, that there are going to be significant revenues if we impose a cap and trade system, and Europe, and the rest of the developing world, is moving in that direction. I think we are going to have to fall into sync with that process over a period of time. So, I think there will be a significant revenue stream out there, and

it would be a tragedy if we didn't invest that revenue stream significantly in R&D.

But you have got a standup period in the interim, and I don't want to say that $1 billion on energy R&D is not worth spending. It is. $1 billion in the earlier research stages can do a lot, but getting even to $1 billion is going to be tough to ask for. Obviously, you have to even this in over a period of time. I would also just urge you to think about other potential revenue sources that might be out there, and there may be some royalty sources that you want to look at.

Dr. VAN ATTA. I guess I am an optimist, in the sense of saying that you know, first of all, you have to start things up, and if you are going to start things up, you need to do it in a focused way, that gets things going on a success path. So I think if one could start with $300 million in a focused way, not try and take on everything, you would be doing something very good, and that probably would be, in my mind, probably starting $300 million on renewables, as the area where, I think, the most dollars can do the most advantage.

Scaling then becomes an issue, and I think you do have a question as to how do you scale, and I think, and what is the right amount of money. Too much money is also not a good thing. I think you want to have an organization that is somewhat lean. I think if they could scale up to $1 billion, and then prove that they could do good with that, and then deserve more, that is fine. There is a point at which even DARPA agrees that more money is probably not a good thing, in order to do what its unique role is. Otherwise, it is probably going way beyond its original charters into, in fact, development type programs and projects, as opposed to the kind of front-end advanced development proof-of-concept work.

So, maybe I am a little different in mind, in terms of where I think this fits in the scale of things. I think if we can get the $300 million, get something started in a focused way, sort of like the Presidential initiatives when DARPA was first created, in terms of three key things, get that up and running, then say all right, based upon that, let us move forward, based upon our success path with the objective of at least $1 billion, and if we can go further than that, if it is justified, fine.

DARPA didn't start off with a dollar bogie. DARPA started off with a problem bogie. And I think the problem here is that we have to focus on getting the momentum going. If there is a way of getting more money in at the start, fine, but you know, starting with too much money can be a problem, too. I will use SDI as an example, too much money, there is a problem of too much money chasing too few ideas.

Right now, we have lots of ideas up there. I think getting some money out there to start sifting and sorting amongst those ideas is crucial. Starting with $300 million, if that is what we have got, let us start with it. If we can get some more, $500, that would be good, too.

Dr. FORREST. Just to circle back on that, just very briefly, is we have to understand that the energy problem is probably, by all accountings, the biggest crisis that humanity is facing in this century. There are six billion people on this planet. Two billion people

today do not have access to electricity. Now, that is not going to last for long. Those two billion people are going to be burning very dirty, the dirtiest form of coal and fossil fuels.

If you think we have a problem now, it is only beginning, so we have to first understand the challenge, the level of the crisis. We will, this country will find a way. I couldn't, as I said before, I can't tell you the right level of funding, but we really have to make it match the situation. We have to understand that the situation we are finding ourselves in today, both from a competitive, security, and environmental aspect. And if we do that, and start marching forward, we will find that right number.

Chairwoman GIFFORDS. Well, I want to thank all of our panelists today for coming to testify. It was incredibly interesting discussion, and inspiring as well.

We have a lot of work to do in Congress, and knowing that we have the four of you for resources, and knowing the direction that Chairman Gordon is taking this issue in, I think that we have a lot to look forward to.

Under the rules of the Committee, the record will be held open for two weeks for Members to submit additional statements and any additional questions they might have for the witnesses.

If there is no objection, the witnesses are dismissed, and the meeting is adjourned. Thank you.

Mr. BONVILLIAN. Thank you.

Mr. DENNISTON. Thank you very much.

[Whereupon, at 4:16 p.m., the Subcommittee was adjourned.]

Appendix:

Additional Material for the Record

I

110TH CONGRESS
1ST SESSION

H. R. 364

To provide for the establishment of the Advanced Research Projects Agency-Energy.

IN THE HOUSE OF REPRESENTATIVES

JANUARY 10, 2007

Mr. GORDON of Tennessee introduced the following bill; which was referred to the Committee on Science and Technology

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A BILL

To provide for the establishment of the Advanced Research Projects Agency-Energy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. FINDINGS.

The Congress finds the following:

(1) The United States faces a range of energy challenges that affect our economy, security, and environment. Fundamentally, these challenges involve science and technology.

(2) The Department of Energy already has some of the mechanisms necessary to promote long-

term research, but it lacks the mechanisms for quickly transforming the results into technology that meets national needs.

(3) A recent report of the Secretary of Energy's Advisory Board's Task Force on the Future of Science Programs at the Department of Energy concluded that "America can meet its energy needs only if we make a strong and sustained investment in research in physical science, engineering, and applicable life sciences and if we translate advancing scientific knowledge into practice".

(4) The Department of Defense, since 1958, has used its Defense Advanced Projects Research Agency (DARPA) for aggressively addressing real-time defense problems through targeted programs of research and technology development that have improved our national defense through transformation technologies.

(5) The National Academy of Sciences' report entitled "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" recommends creating a new agency within the Department of Energy to sponsor "creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself

cannot or will not undertake such sponsorship, where risks and pay-offs are high''. Such an organization would be able to accelerate the process by which research is transformed to address energy-related economic, environmental, and security issues to decrease dependence on foreign energy through targeted research and technology development.

SEC. 2. ADVANCED RESEARCH PROJECTS AGENCY-ENERGY.

(a) ESTABLISHMENT.—There is established the Advanced Research Projects Agency-Energy (in this Act referred to as ''ARPA–E'') within the Department of Energy.

(b) GOAL.—The goal of ARPA–E is to reduce the amount of energy the United States imports from foreign sources by 20 percent over the next 10 years by—

(1) promoting revolutionary changes in the critical technologies that would promote energy independence;

(2) turning cutting-edge science and engineering into technologies for energy and environmental application; and

(3) accelerating innovation in energy and the environment for both traditional and alternative energy sources and in energy efficiency mechanisms to

decrease the Nation's reliance on foreign energy sources.

(c) DIRECTOR.—ARPA–E shall be headed by a Director who shall be appointed by the Secretary of Energy. The Director shall report to the Secretary.

(d) RESPONSIBILITIES.—The Director shall administer the Fund established under section 3 to award competitive grants, cooperative agreements, or contracts to institutions of higher education, companies, or consortia of such entities which may include federally funded research and development centers, to achieve the goals stated in subsection (b) through targeted acceleration of—

(1) energy-related research;

(2) development of resultant techniques, processes, and technologies, and related testing and evaluation; and

(3) demonstration and commercial application of the most promising technologies and research applications.

(e) PERSONNEL.—

(1) PROGRAM MANAGERS.—The Director shall designate employees to serve as program managers for each of the programs established pursuant to the responsibilities established for ARPA–E under sub-

section (d). Program managers shall be responsible for—

(A) establishing research and development goals for the program, including through the convening of workshops and conferring with outside experts, as well as publicizing its goals to the public and private sectors;

(B) soliciting applications for specific areas of particular promise, especially those which the private sector cannot or will not provide funding;

(C) selecting research projects for support under the program from among application submitted to ARPA–E, following consideration of—

(i) the novelty and scientific and technical merit of the proposed projects;

(ii) the demonstrated capabilities of the applicants to successfully carry out the proposed research project; and

(iii) such other criteria as are established by the Director; and

(D) monitoring the progress of projects supported under the program.

(2) HIRING AND MANAGEMENT.—In hiring personnel for ARPA–E, the Secretary shall have the hiring and management authorities described in section 1101 of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 (5 U.S.C. 3104 note). For purposes of subsection (c)(1) of that section, the term of appointments for employees may not exceed 5 years before the granting of any extension.

(f) COORDINATION.—The Director shall ensure that the activities of ARPA–E are coordinated with those of other relevant research agencies, and may carry out projects jointly with other agencies.

SEC. 3. FUND.

(a) ESTABLISHMENT.—There is established in the Treasury the Energy Independence Acceleration Fund (in this Act referred to as the ''Fund''), which shall be administered by the Director of ARPA–E for the purposes of carrying out this Act.

(b) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated to the Director of ARPA–E for deposit in the Fund $300,000,000 for fiscal year 2008, $375,000,000 for fiscal year 2009, $468,000,000 for fiscal year 2010, $585,000,000 for fiscal year 2011, $732,000,000 for fiscal year 2012, and

$915,000,000 for fiscal year 2013, to remain available until expended.

SEC. 4. RECOUPMENT.

(a) REQUIREMENT.—Not later than 180 days after the date of enactment of this Act, the Secretary shall establish procedures and criteria for the recoupment of the Federal share of each project supported under this Act. Such recoupment shall occur within a reasonable period of time following the date of the completion of such project, but not later than 20 years following such date, taking into account the effect of recoupment on—

(1) the commercial competitiveness of the entity carrying out the project;

(2) the profitability of the project; and

(3) the commercial viability of the technology utilized.

(b) WAIVER.—The Secretary may at any time waive or defer all or some portion of the recoupment requirement as necessary for the commercial viability of the project.

(c) AVAILABILITY OF FUNDS.—Revenue received by the Federal Government pursuant to this section shall be deposited into the Fund and shall be available with further appropriation to fund future grants, contracts, and cooperative agreement as authorized by the Director.

(d) DEFINITIONS.—For the purposes of this section—

(1) the term "for-profit entity" means a licensee or successor in interest to a venture member, or any other for-profit person or entity, or combination of such persons or entities, that earns or accrues amounts subject to this section;

(2) the term "product or invention supported by or produced as a result of funding under this Act" includes any product or invention of a venture member based on or using any technology or invention arising out of a venture funded under this Act; and

(3) the term "revenue generated by or resulting from a product or invention" includes revenue derived from the sale or licensing of patents or other rights with respect to the product or invention.

SEC. 5. ADVICE.

(a) ADVISORY COMMITTEES.—The Director may seek advice on any aspect of ARPA–E from—

(1) existing Department of Energy advisory committees; and

(2) new advisory committees organized to support the programs of ARPA–E and to provide advice and assistance on—

(A) specific program tasks; or

(B) overall direction of ARPA–E.

(b) APPLICABILITY.—Section 14 of the Federal Advisory Committee Act shall not apply to advisory committees organized under subsection (a)(2).

(c) ADDITIONAL SOURCES OF ADVICE.—The Director may seek advice and review from the National Academy of Sciences, the National Academy for Engineering, and any other professional or scientific organization with expertise in specific processes or technologies under development by ARPA–E.

SEC. 6. ARPA-E EVALUATION.

After ARPA–E has been in operation for 54 months, the President's Committee on Science and Technology shall begin an evaluation (to be completed within 12 months) of how well ARPA–E is achieving its goals and mission. The evaluation shall include the recommendation of such Committee on whether ARPA–E should be continued or terminated, as well as lessons-learned from its operation. The evaluation shall be made available to Congress and to the public upon completion.

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SECTION-BY-SECTION ANALYSIS OF H.R. 364

Summary

H.R. 364 establishes an Advanced Research Projects Agency for Energy within the U.S. Department of Energy. Modeled after the Department of Defense's Defense Advanced Research Projects Agency, ARPA–E is a new program charged with the mission of reducing U.S. dependence on oil through the rapid development and commercialization of transformational clean energy technologies. This bill follows on the recommendations of the National Academy of Sciences' report *"Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future."*

Section-by-Section

Section 1. Findings

The U.S. can meet long-term energy challenges through sustained investment in energy research programs at DOE augmented by an innovative and aggressive new energy technology development effort based on the same operating principles that make DARPA successful.

Section 2. Advanced Research Projects Agency–Energy

Establishes the Advanced Research Projects Agency–Energy (ARPA–E) within the Department of Energy. Similar to the Department of Defense's successful Advanced Research Projects Agency (DARPA), this new organizational structure will be better positioned to support revolutionary and transformational energy research where risk and pay-offs are high.

The stated goal of ARPA–E is to reduce the dependence of the U.S. on foreign energy sources by 20 percent over the next 10 years. To achieve this ARPA–E should support targeted high-risk, high pay-off research to accelerate the innovation cycle for both traditional and alternative energy sources and energy efficiency. ARPA–E shall be headed by a Director, appointed by the Secretary, who will administer competitive grants, cooperative agreements, contracts or similar transactions with universities, industry and consortia which may include federal labs.

Organization of ARPA–E will be very flat and nimble to avoid bureaucratic impediments that stifle innovation today. The Director shall designate program managers who will have flexibility in establishing R&D goals for the program, publicizing goals, issuing solicitations and selecting projects for support as well as monitoring their progress. Projects will be chosen based on factors such as novelty, scientific and technical merit, applicant's capabilities and other criteria as the Director determines. ARPA–E will have authority to hire specialized science and engineering personnel to be program managers. (This is similar to DARPA and HS–ARPA.)

In addition, the Director shall ensure that ARPA–E's activities are coordinated with other federal research agencies and that ARPA–E may carry out projects jointly with other agencies.

Section. 3. Energy Independence Acceleration Fund

Establishes the Energy Independence Acceleration Fund administered by the Director of ARPA–E. Funding is authorized from FY 2008 thru 2013 ramping up 25 percent per year from an initial authorization of $300 million to $915 million.

Section 4. Recoupment

If a project is successful the Federal Government can recoup some of its original investment. The provision allows the Secretary complete flexibility in developing recoupment agreements, and the ability to waive it entirely if necessary for the commercial viability of a project. All recouped funds will be returned to the Energy Independence Acceleration Fund.

Section 5. Advisory Committee

The ARPA–E Advisory Committee may seek advice either from an existing DOE advisory committee or may establish a new advisory committee. If the Director of ARPA–E requires industry advice, a panel to advise on a specific technology area, or to hire an outside consultant, this provision provides the appropriate authorities.

Section 6. ARPA–E Evaluation

At the end of five and one-half years, the President's Committee on Science and Technology (PCAST) shall evaluate how well ARPA–E has performed in achieving its goals and mission. The Committee is required to recommend whether ARPA–E should be continued or terminated as well as lessons learned from its operation.