

Written Statement of Dr. Arun Majumdar
Hearing on The Future of ARPA-E
Subcommittee on Energy, House Committee on Science, Space and Technology
February 26, 2019

I would like to extend my thanks to the Chairman, the Ranking Member, and the esteemed members for inviting me to testify on the Future of ARPA-E.

I am currently the Jay Precourt Provostial Chair Professor in the Department of Mechanical Engineering at Stanford University and also the co-Director of the Stanford Precourt Institute for Energy. Before joining Stanford, I was the Vice President for Energy at Google. I remain deeply engaged with energy businesses across the world, either through work at Stanford or as a private citizen advising businesses.

Between 2009 and 2012, I had the honor of serving as the Founding Director of ARPA-E, during which I recruited the first team and helped create ARPA-E's DNA that involved multiple elements:

- recruiting top talent in science, engineering and business using the very important hiring authority that Congress provided.
- a laser focus on the mission of ARPA-E that Congress laid out in its authorization – reducing energy imports, energy efficiency across the economy, reducing greenhouse gas emissions and providing the US with a technological lead
- creating a culture of open debate and discussion within ARPA-E to unleash this talent to identify new opportunities and fund ideas with potential for breakthrough technologies;
- creating a model of operational efficiency, active program management and financial integrity, with the discipline and compassion to sunset futile projects;
- an exemplar of engaging stakeholders via the ARPA-E Energy Innovation Summit as well as a creating a model of partnership with Congress.

Because of these elements and due to the remarkable breadth of new research ideas that ARPA-E funded across the USA, ARPA-E certainly caught the attention of many thought leaders in the US. Here are a few examples of what they said.

At the 2012 ARPA-E Energy Innovation Summit, the Founder, Chairman and CEO of FedEx, Mr. Fred Smith, said “Pound for pound, dollar for dollar, activity for activity it is hard to find a thing the United States has done that is more effective than ARPA-E.” In 2011, Senator Lamar Alexander noted “It is my belief that ARPA-E is one of the bright stars in innovation in the world today, and certainly for our country.” And in the same year, Senator Dianne Feinstein suggested to the then Secretary of Energy, Steven Chu, in a Senate appropriation hearing: “Even though ARPA-E is a new agency, I'd like to ask that you apply ARPA-E program management to other DOE offices.” Bill Gates and his colleagues at the American Energy Innovation Council had high praise for ARPA-E as well. I could go on and on, but I think you get the point.

ARPA-E has been viewed as one of the most valued organizations within the US government for research investments with the goal of making the US the most innovative and globally competitive nation in the world in the energy sector.

This year marks the 10th anniversary of ARPA-E. Therefore, this hearing is very timely indeed to reflect back and ask two key questions: (a) What is the key to ARPA-E's success that needs to be preserved? (b) What else can ARPA-E do to make the US even more successful and globally competitive?

What is the key to ARPA-E's success that needs to be preserved?

ARPA-E is modeled after DARPA that has a 60-year illustrious history during which it helped create the internet, stealth and many other technologies. Similar to DARPA, ARPA-E is an organization that funds research in science and engineering with the purpose that if the research ideas are successful, they will produce breakthrough technologies that will have large commercial impact in the future. These technologies will form the foundation for entirely new industries that do not exist today and make US industries much more competitive in the world.

To fulfill this important mission, it is critical to have the most talented people within ARPA-E, ones who are at the cutting edge of creative research in science and engineering with a deep understanding of how research could create value for society via the private sector. It takes one to be at the cutting edge to recognize what is cutting edge. So in many ways, ARPA-E is all about the people. As the Director, I used my own stature and network in the scientific community to recruit top talent as Program Directors from the best organizations within the US – MIT, Intel, NC State, PNNL, GE, etc. None of my recruits needed a job. They joined ARPA-E to serve the nation and be part of something special as one of the most intellectually stimulating and enriching environments. After 3-4 years they went back to the private sector or academia with their ARPA-E record as a badge of honor. During their time at ARPA-E, they conceived some of the most impactful programs that bridged two or three fields of science and engineering to create something completely new that no one in the world had ever imagined. These include batteries much more advanced than lithium-ion to provide multi-day support for the grid. Or entirely new routes to use biology and agriculture to convert carbon dioxide into fuels.

So my message is the following. It is very important to preserve the special hiring authority Congress has bestowed on ARPA-E and to ensure that the leadership in ARPA-E uses this authority to recruit top talent. One of the best things about the ARPA-E model is that the program directors stay for 3-4 years and then are required to leave. This time constraint puts a level of urgency to make a difference, and this urgency is very important. This needs to be preserved as well.

Finally, much of the research ARPA-E funds is often in the proof-of-concept stage. To go from a successful proof-of-concept to full-scale commercial impact is a long and arduous maturation process, which takes 15-20 years in the energy sector. After all, research on computer networks started in 1968 which eventually produced the internet, but the full commercial impact was felt 25+ years later. The point I am making is the following: It is very important for Congress to be patient in its expectations of commercial impact from ARPA-E funded research. Expectations of short-term success will produce incremental thinking from ARPA-E, and that will defeat the whole purpose of ARPA-E which should be going for the homeruns. What should be asked of ARPA-E is whether there are signs of potential future success, such as: intellectual property creation; follow-on private sector funding after ARPA-E's investment; creation of startup

companies; technologies going into demonstration projects and industrial testing; new manufacturing supply chains being created. We are indeed seeing this happen, but it will take another 5-10 years for large-scale commercial impact.

What else can ARPA-E do to make the US even more successful and globally competitive?

In the last 10 years, a lot has changed in the global energy landscape. Today, three game-changing paradigm shifts are already shaking up this global energy landscape: unconventional oil and gas revolution due to fracking of shale formations; electrification of transportation via lithium-ion batteries; and carbon-free electricity generation from wind and solar. The rapid cost reduction in these technologies due to R&D have create these tectonic shifts in the energy industry.

Despite this remarkable progress, fossil fuels still comprise 80 percent of global energy use. And yet we now know that we have to reduce greenhouse gas emissions with fierce urgency to mitigate the ill effects of climate change. Reducing emissions is a billion-tonne-scale problem and it needs billion-tonne-scale affordable solutions. What are these potential solutions?

They include: grid-scale storage at one tenth the cost of lithium-ion batteries; small modular nuclear reactors at half the construction cost of today's reactors; refrigeration and air conditioning using refrigerants with no global warming potential; zero net energy buildings at zero net cost; using renewables to produce carbon-free hydrogen at the same cost as that from shale gas; decarbonizing industrial heat needed to make steel, concrete and chemicals and reimagining carbon-neutral construction materials; decarbonizing the food and agriculture sector, and leveraging agriculture to suck out carbon dioxide from the air and store it in the ground; and capturing carbon dioxide from power plant exhausts followed by sequestering it deep underground or using it make plastics or even fuels.

What I am describing is nothing short of a new industrial revolution. This is a remake of much of our economy – electricity, automobiles, steel, concrete, oil, gas, food, agriculture, etc. We stand at the doorstep of a colossal change of the energy sector worth \$10 trillion per year, more than 10 percent of the global GDP. This change will impact every human being, and will shape the economy, environment, international security and geopolitics of the 21st century. In short, this global energy transition presents a historic opportunity for every country and region. And the race is on to seize this opportunity. We must ensure that the US remains globally competitive and maintains its technological lead, which is part of APRA-E's mission.

The seize this opportunity we need to create new solutions. These solutions often start from new ideas of breakthrough technologies that are initially too risky or disruptive for the private sector. ARPA-E's mission is to help our scientists and engineers try out a portfolio of new ideas in their laboratories. Many will fail, but if some of these succeed, they will form the foundation of this new industrial revolution.

But here is the key challenge in the US. is that the journey from ARPA-E funded laboratory-scale proof of concept to billion-tonne scale commercial solutions contains multiple valleys of death. We must address these gaps for the US to receive the full economic benefit of ARPA-E investments. Let me propose one option for your consideration.

When faced with global competition in the semiconductor industry in the mid-1980s, DARPA convened 14 US semiconductor companies who would otherwise compete with each other in the market, and created SEMATECH, a not-for-profit consortium that performs R&D to advance chip manufacturing. Some of the funds came from DARPA, but the industry chipped in. A GAO report noted that this government-industry R&D consortium helped improve US industry's technological position while protecting the government's interest that the consortium be managed well and public-funds spent appropriately.

To address the first valley of death post-ARPA-E funding, Congress should seriously think about the lessons learnt from the past, adapt these lessons to the current energy landscape and allow ARPA-E to create such private-public consortia to enable the US energy industry become globally competitive. Such consortia could then nurture ARPA-E funded technologies beyond the proof-of-concept stage, and enable them to mature to pilot demonstration and beyond.

But let me also be very clear that such activity requires additional budget authority for ARPA-E. This should not come at the cost of ARPA-E research funding on new research ideas. When I was the Director of ARPA-E, I was often asked what should be ARPA-E's budget. My answer was very simple. Since ARPA-E was modeled after DARPA, one should look at DARPA's first budget. In 1962, the 87th Congress gave DARPA its first appropriated budget of \$246M. In 2019 dollars, that is roughly \$2B.

If we are serious about creating and leading in a new industrial revolution and compete with China, EU and other parts of the world, Congress should seriously consider ARPA-E's budget authority to be \$1B at the very least. With the best scientific infrastructure and talent in the world, and with the entrepreneurial spirit that is in the American DNA, the US has a remarkable capacity to innovate and deliver on ARPA-E's investments. As Fred Smith implied, this is the best investment public dollars can make and best return on investment that our nation will receive.

I thank you for the opportunity to testify before you today, and I look forward to answering your questions.