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FOSTERING INNOVATION: CONTRIBUTIONS OF THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

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BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

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ENERGY AND NATURAL RESOURCES

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FOSTERING INNOVATION: CONTRIBUTIONS OF THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

TUESDAY, SEPTEMBER 12, 2017

U.S. SENATE,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Subcommittee met, pursuant to notice, at 3:06 p.m. in Room SD–366, Dirksen Senate Office Building, Hon. Cory Gardner, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. CORY GARDNER, U.S. SENATOR FROM COLORADO

Senator GARDNER [presiding]. The Committee will come to order.

Good afternoon everyone, and thank you for your patience as we had to delay the hearing start.

Today the Subcommittee on Energy will hold its second hearing in the 115th Congress. I enjoy the opportunity, always, to work with the Ranking Member, Senator Manchin, to address these key topics in Energy.

During today's hearing we will take a deeper look into the Department of Energy's National Laboratory system. In 2015, the Council to Review the Effectiveness of the National Energy Laboratories stated that the 17 labs of the DOE "are national assets that have contributed profoundly to the nation's security, scientific leadership, and economic competitiveness." I am excited to hear much more about these outcomes today.

The constellation of national labs was born from our desire to harness nuclear energy. Through today's discussion, I suspect our witnesses will enlighten us on the dramatic transformations that the lab system has taken over the last 70 years to continually address our nation's biggest challenges and leaders, and as you are leaders, on the global stage.

The U.S. has been the leader in research and development for years, but China is close at our heels in research spending. How we choose to invest in our national labs and support the scientists within them is critical going forward.

Today I hope to hear more about what has been accomplished with the world-leading unique facilities we have developed so far and insights into how our laboratories incubate creative experts responsible for life-changing outcomes.

If I remember right from chemistry class, and according to my grades I may not have always remembered right, a catalyst is something that promotes or accelerates a reaction or outcome that would not normally happen. I believe our national labs are catalysts that have accelerated or made possible many innovations.

Our national labs harness nuclear power. They have shown us how to draw energy from the sun and the wind. Medical imaging was made possible by national lab materials discoveries. They have continued to push the limits of computational power and software tools to analyze the most difficult problems to keep us all safe, both from nuclear weapons and even in the car as we drive.

The national labs are truly a catalyst. The ability of national labs to encourage innovation, foster collaboration and accelerate outcomes results in significant value and impact.

I expect our witnesses today can probably teach us a thing or two about catalysis science. Beyond that, I definitely look forward to hearing them elaborate on the discovery environment within the labs and examples of results providing societal value. I believe the national labs have demonstrated a great ability to our delivery on science over several generations and Administrations and will continue to enhance the lives of millions of Americans.

I would like to welcome our four witnesses: Dr. Brian Anderson, Dr. Kearns, Ms. Ratnayake, if I got it right, and Dr. Tumas; but I will start first with turning to Senator Manchin for comments and introduction.

STATEMENT OF HON. JOE MANCHIN III, U.S. SENATOR FROM WEST VIRGINIA

Senator MANCHIN. Thank you, Mr. Chairman. I want to thank you for scheduling this hearing and for your work and support of our country's national lab system.

Between the National Energy Technology Lab in Morgantown, West Virginia, and the National Renewable Energy Lab that calls Colorado home, Senator Gardner and I have a firsthand understanding and appreciation for the critical work that is done by the good men and women who make our national lab systems.

I was happy to work with Senator Capito on the Appropriations Committee to ensure that NETL is funded at $72.66 million for NETL research and development and at $58.68 million for NETL infrastructure and operations for the Fiscal Year 2018 Energy and Water bill.

I also want to thank Senator Heinrich for his leadership on the Energy Technology Maturation Act of 2017. This bill is a commonsense approach to ensuring that the Department of Energy can incentivize small businesses and private sector interest to partner with the national laboratories to advance the growth of lab-based technologies into commercial markets. I am happy to be a co-sponsor also with him.

And last, but not least, I appreciate that our witnesses are joining us today for this very timely discussion. In particular, I want to recognize Dr. Brian Anderson who leads the West Virginia University Energy Institute. I have worked with Brian for some time, and I am glad he is here today to give us the University Partner's perspective on the importance of the work being done in Morgantown at the National Energy Technology Lab.

The network of 17 national labs have developed over a long history with many originating during the time of the Manhattan Project. The national labs focus on energy innovation, scientific research, national security and environmental stewardship. The national labs work at the forefront of basic science and fundamental research, and the work that our national labs do has led to some of the most significant innovations of the last century. Just a couple examples include making digital recording technology a reality and x-ray vision. It was actually the national labs who discovered the difference between good and bad cholesterol.

Over the past year, the national laboratories provided expertise and support for the joint comprehensive plan of action which, as we know, is the Iran Nuclear Agreement and addressing and evaluating the impact of the leak at the Aliso Canyon Underground Natural Gas Storage Facility.

Another unique but important aspect of our lab systems are user facilities. The labs have unique and leading-edge user facilities such as x-ray and neutron sources, advanced accelerators and laser facilities, and nanomaterials facilities that benefit the research of over 33,000 researchers from academia, research institutions and private industries, annually.

The lab that I hold near and dear to my heart is the National Energy Technology Lab (NETL) which is headquartered in Pittsburgh. The NETL is the only government-owned, government-operated, GOGO lab, in the national lab system. Housed under the Department of Energy's Office of Fossil Energy, it celebrated its 100th anniversary several years ago in recognition of a history of research stations dating back to 1910.

NETL implements a broad range of energy and environmental research and development programs that include enabling domestic coal, natural gas and oil to economically power our nation's homes, businesses and transportation in an efficient, environmentally sustainable way.

With a sprawling complex in Morgantown, West Virginia, that employs approximately 612 people, NETL has delivered some of our most important energy innovations in recent decades. NETL has expertise in coal, oil and gas technologies as well as energy systems and international energy issues. For example, its work regarding the extraction of rare earth elements (REE) from coal byproducts is a testament to NETL's ability to think creatively to solve our nation's energy security and supply chain challenges.

I was happy to help secure funding for the REE research in the Fiscal Year 2018 Energy and Water bill and look forward to working with WVU and NETL further as we work to redevelop a domestic energy industry for rare earth elements.

And as Dr. Anderson will tell us today, NETL's partnerships, cooperative research and development agreements, financial assistance and contractual arrangements with universities and the private sector have led to extraordinary collaboration amongst the world's leading minds in energy innovation.

West Virginia has a history of producing energy for the rest of the country and NETL has played a big role in ensuring that we are striving to do it in cleaner, more efficient and more cost-effective ways. That has contributed greatly to West Virginia's role as a net energy exporter.

In conclusion, the national labs are the lifeblood of our innovation. The collaborative nature of this lab system makes our lab system dramatically important to the future of science and energy innovation in this country; therefore, the proposed budget cuts to our national lab system are concerning to say the least. The Fiscal 2018 proposed budget would cut $1.25 billion in funding from the national labs which could eliminate about 7,000 jobs. That is obviously going to result in a brain drain that will cause major disruption to the ongoing work at these facilities, at our universities and in the private sector.

I look forward to working with Chairman Gardner and my colleagues to ensure our nation's labs are given the resources they need to continue their vital work.

Thank you all for being here.

Senator GARDNER. Thank you, Senator Manchin, and thank you for the introduction of Dr. Anderson, one of our witnesses today.

Senator Duckworth, I know, has an introduction as well.

STATEMENT OF HON. TAMMY DUCKWORTH, U.S. SENATOR FROM ILLINOIS

Senator DUCKWORTH. Thank you, Mr. Chairman.

It is a real pleasure to introduce Dr. Paul Kearns, Acting Director at Argonne National Laboratory, which is in my home State of Illinois.

I was warned by my staff not to make this claim because we do not actually have the hard data for it, but I am going to claim it anyway—I think, with our two national labs, we have more particle physicists per capita than any other state in the nation and I dare anyone to come up with the data to prove me wrong.

[Laughter.]

Senator GARDNER. I am going to have to look into that.

Senator DUCKWORTH. Go for it. Go for it.

Senator FRANKEN. I am on it too.

Senator DUCKWORTH. There you go, there you go.

[Laughter.]

Dr. Kearns heads up one of those critical, critical, crown jewels of scientific innovation in Illinois. We also have the privilege of having the first national lab in the country, Argonne.

Dr. Kearns has a long and decorated career as a scientist having served across the country at several national labs. His experiences are especially relevant to this hearing on innovation.

At Argonne, Dr. Kearns guides the development and implementation of the laboratory's strategic vision. He is leading Argonne in its efforts to continue delivering world class performance in science and technology, operations, employee health and safety and environmental protections.

Dr. Kearns promotes a culture of innovation and collaboration within the laboratory which will serve it well as it enters into its 75th year, and he also promised to put in a good word for Fermilab, our other national laboratory as well. So I am incredibly happy that Dr. Kearns was able to join us for this very important conversation.

Thank you for being here and welcome.

Thank you, Mr. Chairman.

Senator GARDNER. Thank you, Senator Duckworth.

We will begin with the lab that just happens to be located in the great State of Colorado, the National Renewable Energy Laboratory, Dr. William Tumas, Associate Laboratory Director, Materials and Chemical Science and Technology.

Dr. Tumas is responsible for overall leadership, management, technical direction and workforce development of the materials and chemical science and technology capabilities at NREL, spanning fundamental and applied research and development for renewable energy and energy efficiency.

Dr. Tumas received his undergrad degree in chemistry from Ithaca College, his Ph.D. from Stanford and then did his post-doctoral research at Caltech. I hope you have paid your student loans.

[Laughter.]

With that, I look forward to hearing your testimony. Thank you.

STATEMENT OF DR. BILL TUMAS, ASSOCIATE LAB DIRECTOR, MATERIALS AND CHEMICAL SCIENCE AND TECHNOLOGY, NATIONAL RENEWABLE ENERGY LABORATORY

Dr. TUMAS. Thank you, Senator Gardner, thank you, Ranking Member Manchin and the rest of the Subcommittee for the opportunity to talk about the value of the national laboratories today.

As Senator Gardner said, I'm the Associate Lab Director for Materials and Chemistry at the National Renewable Energy Lab, commonly called NREL. I lead programs in material science, nanoscience, chemistry, energy storage, solar energy, hydrogen and fuel cells. I also lead an Energy Frontier Research Center in Materials by Design.

I started my career at DuPont Central Research and six years later I moved to the Los Alamos National Laboratory and in 2010 I moved to NREL.

What attracted me to the national labs, as we heard from our Chair and the Ranking Member, is the ability to really address big science challenges, complex problems and to work in a real teeming science environment with superb colleagues and excellent facilities.

As we heard already, the national labs have contributed significantly to our national security, our energy security, our economic prosperity and our scientific leadership.

Other examples include optical disc recording to explosive detection, many examples we heard from our everyday lives can track their origin to national laboratories, strengthening the metal on aircraft, 22 elements were discovered at the national laboratories, everything from lead-free solder to nuclear deterrents to airport security.

Another thing that I'd like to point out is the national labs really are one of the only groups that you can pull together, essentially, on a moment's notice to create very large, multi-disciplinary teams to tackle really pressing needs, whether it's disaster forecast, disaster recovery or other things that are even classified that we can't discuss in this arena, there are many examples today.

The national labs, as we heard, have a scientific use, set a specialized science user facilities. They also have a pool of highly-talented individuals and researchers, and that really forms the backbone of a national lab system that I would purport really is a huge engine for maintaining and developing our country's science and technology capability.

In addition to allowing access to tens of thousands of scientists from universities and industry to the user facilities, the lab serves as a magnet and, I would argue, a training ground for our next generation of scientists and engineers.

There are a number of examples where we've seen significant impact in energy as well. Cost-efficient shale gas can trace its way back to national lab work. We'll hear about carbon capture and storage, perhaps, from NETL and the University of West Virginia. Photovoltaics, near and dear to my heart, from our own laboratory, and I'm sure we'll hear about advanced battery technologies from our colleague from Argonne.

NREL work encompasses fundamental science but also applied science and engineering, technical analysis and assessment and systems integration. And we're proud to have made significant contributions in partnership with many others to a number of areas. Thin film solar cells are made by a U.S. company and create tens of gigawatts of clean power. Multi-junction, high-efficiency solar cells power satellites and are finding increasing use by the U.S. military for energy.

The U.S. industry, solar industry, employs over 370,000 employees today. The wind industry employs 100,000 and is on track for a quarter million employees in the U.S. by 2020.

NREL has contributed significantly to power variable power strategies and pitch control that are used in almost every turbine in many, many states in our country.

Making energy more affordable and domestically available, of course, also makes U.S. industry more competitive. In addition to working on affordability, NREL works a lot on resiliency. Through our energy systems integration facility, we work with other laboratories, you'll hear examples from Duke Energy today, on trying to make the grid more stable, more reliable and more secure. And we have a co-lead of 14 lab consortium that aims to modernize our grid and also guard it against both manmade and natural threats.

Despite all these great advances, we live in a world of great opportunity and a world of great challenge. Supercomputers coupled with experiment can help us discover materials; but in the future, it can also help us design entirely new processing concepts that could lead to advanced manufacturing. Understanding the Earth subsurface is critical for fossil fuel extraction, for nuclear waste disposal and for maintaining and assuring high-quality water resources across our country.

From a catalysis science standpoint, Senator Gardner, I'm fascinated by what we can do in the future of taking carbon dioxide and not thinking of it as a waste product, but actually converting it to materials and to products of commerce.

In energy, we aren't done yet. There's still much to be done on cost, on efficiency, on accelerating the deployment and on getting more energy on to the grid, a true above all strategy. As we'll hear from our colleagues, likely, energy storage is critical as well.

Through the energy materials networks we've seen that laboratories now can work on big data, computation and experiment and partnership with industry and companies and address a myriad of challenges, like lightweight materials, electrocatalysis for hydrogen production and for fuel cells, caloric materials for refrigeration and one that I like that we lead with NREL with three other labs, looking at photovoltaic materials for photovoltaic modules. So we certainly aren't done yet. Continued innovation is critical.

I think it's unrealistic to expect the private sector, though, to pick up the massive R&D void that significant curtailment in our federal R&D budgets could cause. In fact, I would argue that the Bell Labs, Westinghouse Labs and, as of last year, my own former employer, DuPont Central Research, don't even exist anymore.

Our current ecosystem really depends much more on public-private partnerships between national laboratories and industry and companies, and that's what's needed to turn scientific discoveries into beneficial use.

Success comes not only from fundamental research on materials discovery, as we've seen in solar and batteries, but also laboratory engagement with partners on devices, prototypes, testing, reliability and durability, the entire technology development spectrum.

We're not the only country making major investments. As you know, other countries are making massive investments, as Senator Gardner told us.

Cutting-edge science is going to be critical to the future of America and it's going to be critical to maintain our competitive edge. And I would argue if we fail to take advantage of the science assets and the prior investments already made, we risk depending on others for the ideas, knowledge and the innovation we surely will need in the future.

So I'd just like to close by telling you that, in summary, national labs bring an unmatched expertise, I think, in science, but also a very strong and very key link to connecting science to the technological advances that we require.

With that, I want to thank you for the opportunity to talk to you and thank you for your leadership.

[The prepared statement of Dr. Tumas follows:]

Prepared Statement of Dr. Bill Tumas
Associate Lab Director
Materials and Chemical Science and Technology

U.S. Department of Energy, National Renewable Energy Laboratory
For the Senate Committee on Energy & Natural Resources
Subcommittee on Energy Hearing on
"Fostering Innovation: Contributions of the Department of Energy's National Laboratories."

September 12, 2017

Chairman Gardner, Ranking Member Manchin, members of the Subcommittee, thank you for this opportunity to discuss the importance of the Department of Energy's National Laboratories, and the value they provide to our country's security, economic prosperity, and science leadership.

My name is Bill Tumas, and I am the Associate Laboratory Director for Materials and Chemical Science and Technology at the National Renewable Energy Laboratory (NREL), in Golden, Colorado. Most of my career has been devoted to understanding and controlling chemical reactions and the properties of materials for sustainable products, energy conversion, and energy storage, as well as the safe disposal of chemical weapons. I have been associated with the federal research and national laboratory system for 24 years.

At the Los Alamos National Laboratory (LANL), I directed the Applied Energy Programs and held leadership positions in basic and applied chemistry and materials, as well as energy storage. Currently, at NREL, I lead programs on solar energy conversion; materials discovery, synthesis and development; hydrogen production and storage; and fuel cells. At both LANL and NREL, I have led multi-lab consortia that included other national laboratories, university researchers, and industry. Today I also direct the Energy Department's Energy Frontier Research Center focused on Next Generation of Materials by Design.

My career began in the private sector at DuPont Central Research as a research scientist and project leader working on catalysis and environmental chemistry. My research activities have resulted in multiple patents and publications. This combination of industrial and national laboratory experience has helped me gain perspective on the challenges and impacts associated with scientific discoveries and how they may be transitioned into marketable products of value to society.

Labs Use Science To Benefit the Nation
A strong national laboratory system is a vital component of our country's future. Every day our national laboratories work collaboratively with industry and our country's top academics to find solutions to advance basic science and applied technology, addressing many of our nation's most critical challenges in the areas of national security, economic competitiveness, and advanced energy. Wherever we may look, the fruits of decades of innovation from our national labs abound.

In science, the labs have led the world in physics, chemical, biological and computer sciences, and increasing our understanding of the fundamental interactions of the physical environment. National labs have revolutionized materials with widespread applications in energy, transportation, and manufacturing. For national security, our national labs have ensured that the U.S. nuclear deterrent is maintained and remains safe, while undertaking global initiatives to curb the proliferation of weapons of mass destruction. Technologies for security at airports can be traced back to research at our national labs. In transportation, national laboratories created computer modeling and materials that has made cars and planes safer, stronger, and more efficient. Other computational models now reliability predict natural disasters and infrastructure recovery.

So that our nation continues to benefit from our wealth of domestic energy resources, national laboratories are researching advancements in virtually all energy technologies. Examples include carbon capture and storage work performed by a team under the leadership of the National Energy Technology Laboratory, the advanced battery technologies from Argonne National Laboratory and others, and the solar photovoltaic technologies produced by my laboratory, NREL. Our discoveries have and will continue to pave the way for growing industries in the United States.

We are able to accomplish goals such as these because the nation has invested in our national labs to build and maintain a collaborative constellation of scientific and engineering facilities that are unmatched by any other nation. Our deep scientific strengths come with having teams composed of many of the world's very best researchers, across all relevant disciplines, coupled with a built-in expectation of inter-lab cooperation. My personal experience building scientific teams has resulted in collaborative research projects with 10 different national laboratories. Collaborations tap the scientific strengths of each participating laboratory while bringing efficiency to the national lab system.

Labs' Unparalleled Capabilities Drive U.S. Innovation
The combination of capabilities and expertise at national labs has served our Nation well. They provide a huge engine for developing and maintaining the nation's science and technology capability. This is a major reason the United States has long led the world in technological innovation, which we've learned is a driving force in our nation's vital economic competitiveness. Highly specialized scientific and engineering facilities form the backbone of the national lab system. These facilities,

coupled with a pool of exceptionally talented individuals, give the labs capabilities found nowhere else.

These facilities are of course essential to the research and development (R&D) conducted by the labs themselves, and those designated as "user facilities" also serve as singularly capable tools to conduct the science undertaken independently by universities and the private sector. They also provide a training ground for the next generation of scientists and engineers, providing access to cutting-edge research capabilities for tens of thousands of industry and university scientists.

For example, a research group may schedule time to use the SLAC Linear Accelerator Laboratory's Linac Coherent Light Source, which operates as the most powerful x-ray laser in the world. In our Energy Frontier Research Center, we collaborate with SLAC to study the "dance" between electrons and vibrations in a series of experiments to better understand, improve, and synthesize new semiconductor materials.

National labs also provide high-performance computing systems including the National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory and the Leadership Computing Facilities supercomputers at Argonne and Oak Ridge, which have enabled a variety of advances for both leading scientific and industry users. The Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, and Sandia national laboratories are also leading the Exascale Computing Project, which aims to develop supercomputers that run 50 times faster than today's leading supercomputers within the next six years.

NREL Research for Advanced Energy Solutions

At my own Lab, NREL, we designed and built the Energy Systems Integration Facility (ESIF)—a DOE user facility uniquely dedicated to developing and testing the new technologies and systems we need to modernize our entire electricity grid. The challenges of incorporating our all-of-the-above energy strategy into the grid, while maximizing affordability and resiliency, are great. America's electric utilities need to reduce the risk of incorporating high levels of variable generation sources, and research underway at ESIF is doing just that.

Employing time-series modeling, big data, and visualization tools that are only feasible through use of a high-performance computer, ESIF's researchers this year completed the Eastern Renewable Generation Integration Study, or "ERGIS," which is providing grid operators with the kind of real-time supply and demand modeling capabilities heretofore unavailable anywhere. Duke Energy is also using ESIF's capabilities to test new equipment and how it pairs with software used for grid operations.

ESIF is also home to the Consolidated Utility Base Energy project, or "CUBE," which was developed for the U.S. Army's forward operating bases. The CUBE helps to integrate solar and battery power systems with these bases' diesel generators, providing reliable energy to remote outposts while using up to 30 percent less fuel. CUBE will save money and reduce the troop fatalities that have been associated with fuel transportation.

ESIF teams are similarly at work solving the challenges we face from an increasingly autonomous complex grid that , and the complexities of incorporating rooftop solar power systems, smart meters, and internet-connected appliances into the existing infrastructure. New control systems are needed for home power systems, the distribution grids they feed into, and the larger transmission grid, possibly leading to a "self-healing" or autonomous grid that responds to changing loads and generation sources without the need for grid operators to step in. As an example of multi-lab collaboration, NREL co-leads the Grid Modernization Laboratory Consortium, a collaboration of 14 national laboratories, developing the systems needed to provide resilient, reliable, secure and affordable electricity for decades to come.

NREL efforts encompass fundamental science, applied science and engineering, technical analysis and assessment, and systems integration. NREL's efforts, and those of the national lab system, have helped changed the energy landscape significantly:

- Over the last two decades we have seen significant increase in the performance of solar cells and a reduction in the cost. The costs now rival traditional electricity generation, with deployment of more than 60 gigawatts of solar globally last year alone (the equivalent of roughly 60 nuclear reactors). Solar now constitutes an $84 billion U.S. industry.
- Wind energy has moved from an engineering curiosity to a common sight across many states with an average contracted sales price of approximately 2 cents per kilowatt-hour, for projects that signed agreements in 2016 and the first half of 2017.
- Wind energy provides a steady source of income for farmers and ranchers across the nation, primarily in America's heartland, and also provides the fastest-growing job in the United States: wind turbine technician.
- America's heartland is one of the world's largest biomass resources for domestically sourced biofuels, bio-based products, and jobs.
- The all-of-the-above energy strategy includes renewable resources that have provided more than half of all new power generation capacity since 2008. Cumulative U.S. renewable capacity now totals 232 gigawatts, or more than 20 percent of the nation's generating capacity.

In addition to making energy more affordable and domestically available, these and other advances will continue to make U.S. industry more competitive. From a resiliency standpoint, our understanding of the electric grid has improved markedly so that we are better able to endure transient conditions—like extreme demand or production shortfalls—with reduced disruption.

The resulting transformation of our nation's energy system is creating opportunities for hundreds of thousands of new domestic jobs. An estimated 6.4 million U.S. workers are employed in the design, installation, and manufacture of energy products and services. Advanced energy technological breakthroughs are fueling this growth and bolstering American competitiveness. The pathway from laboratory to commercial product viability is rarely smooth, nor as short as investors might like, but it is useful to note how far we have come in terms of U.S. jobs:

- Jobs in the solar industry last year grew at a rate 12 times faster than overall job growth in the United States, with more than 373,000 domestic jobs. In 2016, one of every 50 new jobs in the United States was in the solar power industry.
- Today the U.S. wind industry supports more than 101,000 domestic jobs spread across all states, and nearly 250,000 jobs are expected to be needed to support the U.S. wind industry by 2020.
- In 2016, more than 112,500 Americans were employed in the biomass electricity generation and in the biofuels and bioproducts industries.

NREL has helped spur these advances through a number research impacts stemming from integrating fundamental and applied science:

- NREL researchers have worked with US industry to develop solar cells where the thin-film active layers are less than one-tenth the diameter of a human hair. Thin-film solar cells now produce tens of gigawatts of reliable, clean power at extremely low costs.
- NREL scientists developed multi-junction solar cells that power satellites and are being increasingly used for U.S. military applications.
- The National Wind Technology Center led innovations including airfoil designs, pitch control, and variable speed strategies, resulting in broad wind industry adoption.
- NREL's work on microbes and enzymes helped reduce costs and improved process technologies for cellulosic ethanol plants.
- NREL and scientists from the Joint Center for Artificial Photosynthesis (Caltech, Lawrence Berkeley National Lab) engineered and synthesized multi-layer semiconductor devices that directly convert sunlight to hydrogen by splitting water at efficiencies greater than 15%.
- NREL energy systems integration expertise successfully advanced a microgrid system for the Marine Corps Air Station Miramar that draws on batteries and solar photovoltaic energy for its power.

Lab R&D Necessary To Meet Future Challenges

Innovation is the hallmark of the national laboratory complex. Reducing costs, increasing efficiencies, and improving performance for solar, wind, bioenergy, energy storage, grid modernization, and other energy technologies will require pushing the fundamental limits of current materials and technologies as well as creating the new materials, processes, and concepts for next-generation technologies.

For solar, NREL and other labs are working to increase efficiencies and bring costs down to or less than current wholesale electricity costs. NREL and others are exploring new materials such as perovskites that already exhibit high efficiencies and can compete with current technologies on price, can provide coatings that could greatly enhance the efficiency of current technologies, and could lead to printing of high-efficiency, low-cost solar cells, much the way we print newspapers today. For much broader deployment, we will also need to expand solar R&D to include more work on innovative energy storage and power electronics, while ensuring the resiliency, security, and reliability of the grid.

Nanoscale materials such as the quantum dots that now light up high-definition televisions can impact new batteries for energy storage as well as solar windows.

For wind energy, we need to develop higher elevation turbines to access wind across more of the country. We need to model large-scale wind farms for design, performance, and predictability, as well as developing innovative control systems. Lastly, as we go to larger turbines we need to develop on-site manufacturing using new composite materials, such as those being examined in the University of Tennessee-led Institute for Advanced Composites Manufacturing Institute, a public-private partnership.

We also need to harness innovative bioprocesses for new materials, products, and feedstocks. NREL leads the Renewable Carbon Fiber Consortium, comprised of national lab, academic, and industrial partners to demonstrate the cost-effective production of domestic supplies of renewable carbon fiber from cellulosic biomass-derived acrylonitrile for vehicles, wind blades, and products.

The national labs have helped us understand photosynthesis and we are moving forward with universities to advance artificial photosynthesis concepts to convert sunlight directly into fuels. We can also combine advances in carbon with cheap electricity and advances in electrochemistry, materials, catalysis, and synthetic biology to convert carbon dioxide into valuable products and feedstocks.

Harnessing the labs' powerful supercomputers and their interplay with advanced experimental tools will allow us to not only discover new materials more rapidly, but will also help us design and control new processing concepts for advanced manufacturing.

U.S. Innovation Requires Public Sector-Private Sector Partnerships
Innovation is a continuing spectrum and one cannot expect success if any portion of the basic-research-to-product pipeline is ignored. We need to accept that funding R&D is a risk, and while I am not arguing for any relaxation in selection criteria, we need to be realistic—if we are not funding cutting-edge science, with all of its risk,

we are not investing in our collective future.

While the role of private industry is indisputably paramount—national labs after all do not produce finished products—it is simply unrealistic to believe that the private sector can or would fill the R&D void that would be created if federally sponsored research were curtailed. Everyone may talk, and rightfully so, about the discoveries that emerged from Bell Labs—the transistor, lasers, cell phone communication and, my favorite, solar cells. But they don't often add that Bell Labs, as it was then conceived, no longer exists. The truth is that Lockheed's Skunk Works, the notable Westinghouse labs, and my former employer, DuPont's Central Research and Development—corporate research centers responsible for the science that underpins myriad products today—are a thing of the past. The truth is: *These R&D centers are not operating today, or are skeletons of what they once were.*

Despite significant reductions in long-term industrial research, the United States still has a vital innovation ecosystem that stems from partnerships between national labs universities and industry at all phases of the science-to-product ecosystem and are critical for successfully moving scientific discoveries into beneficial use. National labs continue to play a critical role in accelerating innovation. Our industry partners look to the national laboratories for larger-scale and higher-risk fundamental and applied research would not be accomplished in the private sector.

For example, the remarkable success in solar power and energy storage—areas where national labs continue to work closely with industry and with universities—stems from national labs not only discovering new materials but also from foundational research on devices, components, and prototypes, as well as testing, understanding, and controlling reliability and durability. Fundamental to this ecosystem is the critical role-played by private entrepreneurs and small businesses across the nation. There are now a number of innovative mechanisms that give start-up companies access to the national lab capabilities and scientific infrastructure. At NREL, we work to be as innovative in how we connect with the marketplace, and partner with companies, as we are in developing new technology.

NREL's Industry Growth Forum connects newly established technology companies with private sector capital. More than $5 billion has been raised by startup companies presenting at the Forum over the last ten years. Working with the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, NREL pioneered the Small Business Voucher program, which funds lab work with innovative clean energy businesses. A recent program that helps clean energy start-ups mature and demonstrate their technology in a commercial setting is a partnership between NREL and the Wells Fargo Foundation. Twenty companies are in this program and another 30 will be selected in the near future.

Global Competition for Scientific Supremacy

We are not the only country with excellent scientific and engineering capabilities and an interest in innovation. Over the past 30 years, I have been fortunate enough to visit, lecture, or conduct research in foreign universities and labs in the Netherlands, the United Kingdom, France, Brazil, Japan, Germany, Italy, and India. I have found smart, capable, and motivated scientists and engineers everywhere I have been. The United States holds a position of leadership in many, but not all, areas of science, but I assure you from my personal experience that other countries are investing and growing their scientific capabilities. This is in many respects a race and if we falter, the competition is not far behind.

It is no secret that one of the biggest challenges confronting us is how we as a nation can maintain our competitive edge. Our continued leadership in science and innovation is in no way guaranteed—the rest of world is fervently working to capture the innovation flag. The headlines are full of examples of how nations including China, South Korea, and India are investing significant sums to wrest our competitive advantage for themselves.

Dividends From A Renewed U.S. Commitment To Science

If we fail to both take advantage of our current science assets and capitalize on our prior investments, we run a growing risk that we will become dependent on others for knowledge, for ideas, and ultimately for products. Think for a moment about the tax revenue, the jobs, indeed, entire industries that have grown up around the science discoveries mentioned here. All arose from our historic commitment to early-stage research. For these reasons, America will significantly benefit from continued investment in university and national lab scientific advancements. These investments will continue to pay dividends in increased employment, exports, and progress.

The National Renewable Energy Laboratory, along with our partner laboratories across the Department of Energy complex, will continue to help our country succeed in an increasingly competitive global economy—*if and only if* our lifeblood of federal support continues. Our country, indeed our planet, needs the progress science can deliver.

Thank you again for the opportunity to testify today, and thank you as well for the leadership this Subcommittee has shown in supporting the federal research portfolio. I will be happy to answer any questions you may have.

Senator GARDNER. Thank you, Dr. Tumas.

Our next witness, Ms. Ratnayake, who is joining us today, is the Director of Emerging Technology Strategy for Duke Energy. The Emerging Technology organization is responsible for monitoring technology-driven megatrends, identifying and developing utility technologies, and informing Duke Energy's long-term strategy.

Ms. Ratnayake has over a decade of experience in the energy industry as she earned her Bachelor's degree in Business Administration from Berea College and holds a Master's degree in both Business Administration and Diplomacy and International Commerce from the University of Kentucky.

A native of Sri Lanka, Ms. Ratnayake and her husband have two sons.

Thank you for joining us today.

STATEMENT OF ANUJA RATNAYAKE, DIRECTOR, EMERGING TECHNOLOGY STRATEGY, DUKE ENERGY CORPORATION

Ms. RATNAYAKE. Thank you, Senator.

Good afternoon, Chairman Gardner, Ranking Member Manchin and members of the Subcommittee. My name, as I was introduced, is Anuja Ratnayake. I'm the Director of Emerging Technology Strategy at Duke.

Our team, as Senator Gardner mentioned, we are the front end of Duke Energy, where we lead emerging technology pilot projects, including a focus on energy storage, microgrids and renewable energy integration and we continuously work with a number of national labs.

If I may, I'd like to take a moment to acknowledge Duke Energy's customers and employees, who have been affected by Hurricane Irma which has caused widespread devastating damage across Florida, as well as damage and outages in the Carolinas.

In the storm's aftermath personnel safety continues to be the most important focus as we work as quickly as possible to restore power to critical infrastructure and all of our customers.

Today, I appreciate the opportunity to provide the Subcommittee with the perspective of regulated electric utility on the value that the Department of Energy's national labs provide to the electric power sector and our customers.

Duke Energy is one of the largest energy companies in the U.S., serving a population of about 24 million people with electric and gas services. We operate under a regulatory model that prioritizes lowest cost for customers which is met through prudent commercialized technology. This regulatory structure does not incentivize utilities to undertake research, development and early adoption of new and emerging solutions due to the inherent technology risk during the early stages of their commercialization. This creates significant challenges as potentially transformational but nascent solutions are unable to prove their abilities without extensive testing. This is exactly the gap the DOE research programs and ARPA-E fill, serving a vital role for the entire energy sector.

New technologies that are meant to operate on their own can take years of R&D in lab settings before they become scientifically viable and then more R&D in field settings before they're economically competitive.

The energy grid is the largest and most complex machine in the world, comprised of many millions of subcomponents, all working seamlessly together to keep your lights on. Adding a single, new subcomponent, not only requires years of R&D by itself, but it must also prove it can work with the millions of existing components, as well as other future requirements driven by parallel technology developments.

This is not the kind of R&D even the most well-funded, sophisticated company should do on its own. For if a technology doesn't work, it could literally turn out we're dark. This is why we strongly believe the true transformative potential of today's emerging technologies cannot be realized without partners like the national labs. They have expertise with this complex system as well as the unique tools necessary to test and validate emerging tech capabilities.

In my written testimony, I have described specific project examples on increasing efficiency in fossil generation, expanding grid resiliency and enabling seamless renewable integration. The fundamental point of these projects is to position our industry to embrace the changing energy future and evolving customer expectations.

To highlight one of these examples our collaborative partnership with Pacific Northwest National Lab looked at impacts of integrating solar PV on the grid. The lessons learned from this study have proven essential for understanding intermittency and maintaining reliability while we add more solar to our system.

With PNNL we further evaluated leveraging energy storage, smart inverters and demand site management to effectively and economically integrate the increasing levels of solar generation. This work was an essential building block for us to rethink how to plan a smart energy future for our customers.

Our mandate as electric utilities is to provide safe, reliable and affordable energy for our customers. Your support and investments in the national labs enable us to leverage new technologies, to modernize the power grid and stimulate economic growth while we continue to meet this mandate.

The capabilities offered by the national labs are unattainable anywhere else in the industry and are critical to the industry's ability to understand how to better operate and plan our system for the future. This ultimately ensures customers and our communities have the lowest cost, most reliable, resilient and advanced clean energy system in the world.

Thank you for the opportunity to be here today, and I look forward to your questions.

[The prepared statement of Ms. Ratnayake follows:]

Statement of Anuja Ratnayake

Director, Emerging Technology Strategy
Duke Energy Corporation

Before the
Committee on Energy and Natural Resources
Subcommittee on Energy
U.S. Senate

On "Fostering Innovation: Contributions of the Department of Energy's National Laboratories"

Sept. 12, 2017

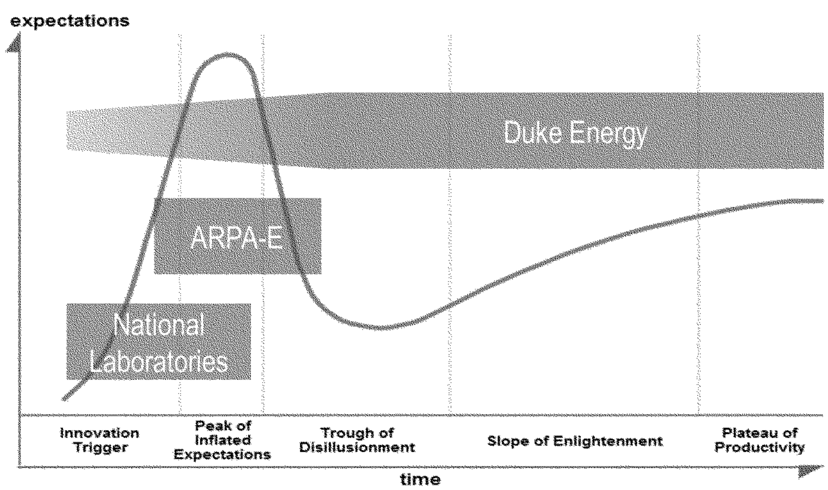
Good morning, Chairman Gardner, Ranking Member Manchin and members of the subcommittee. My name is Anuja Ratnayake, and I serve as Director of Emerging Technology Strategy for Duke Energy. Our team leads emerging technology pilot projects, including energy storage, microgrids and renewable energy integration and work with the National Laboratories.

I appreciate the opportunity to provide the subcommittee with the perspective of a regulated electric utility on the value the Department of Energy's National Laboratories provide to the electric power sector and our customers.

To provide some context for my comments, Duke Energy is one of the largest energy providers in the nation, serving approximately 7.5 million retail electric customers in seven states in the Southeastern and Midwestern regions of the country. We are also one of the largest natural gas distributors in the country, serving approximately 1.6 million customers in the Carolinas, Ohio, Kentucky and Tennessee. Our energy grid, the largest in the United States, is a critical part of our nation's infrastructure. We are investing $25 billion over 10 years to create a smarter, more modern grid that delivers the services our customers expect. Today, the grid stands as a one-way road. In the future, it must become a multilane highway, sending energy and information in both directions. We serve a population of 24 million people, relying on a balanced energy mix that includes natural gas, nuclear, coal, hydropower, solar and wind energy. Our Commercial Renewable Energy business unit operates a large and growing portfolio of solar and wind facilities in 14 states across the United States. We are one of the top five renewable energy companies in the country, having invested more than $5 billion in renewables over the last decade.

As a vertically integrated utility responsible for the full energy spectrum from generation to delivery to the customer, Duke Energy operates under a regulatory model that prioritizes lowest cost for customers and traditionally proven technologies. The current utility regulatory structure does not incentivize research and development (R&D) due to the inherent risks associated with new technologies, which generally result in higher costs compared to mature, proven technologies. This limits our ability to test new technologies and operational methods – and is exactly the reason the National Laboratories and programs such as ARPA-E serve such a vital role for the power sector. Although Duke Energy invests tens of millions annually on R&D (we spent over $30 million last year), it is important to remember that utilities are not R&D tech companies in the Silicon Valley sense. We are integrators and optimizers of proven, commercialized technology – and we're highly regulated in our scope of business.[i]

Most utilities rely on universities, product manufacturers, consortia, and the federal government to sponsor and pursue innovation that benefits our customers. The Department of Energy (DOE) and the National Labs provide focused research on behalf of the utility industry sector. When new technologies emerge, they can take years of R&D before they become viable both scientifically and economically to utilities, as demonstrated by the "Hype Curve" below.[ii] The transformative potential of these new technologies cannot be realized without the National Laboratories.



Source: Hype Cycle from Gartner for IT Leaders Toolkit, Amended by Duke Energy

The Gartner Hype Cycle can be leveraged to help stakeholders understand where technologies are in their life cycle, and to temper expectations on highly hyped opportunities.

The recent scope of other consortia has become narrow, focusing on the short term. Indeed, the National Labs are critical in developing high-impact technologies with long life cycles, such as advanced combustion technologies that are utilized in our power plants, as they have the unique ability to initiate technology transfer from other industries and sectors (such as aerospace and defense) in a way that few other research organizations can. [iii] The National Labs support public and private partnerships that when combined can more effectively transfer emerging technologies to the industry. Often, the R&D that leads to these transformational innovations is simply too complex for any single private enterprise to undertake, which is why we look to the federal government to recognize the importance to help advance technologies to the point where businesses and entrepreneurs can adopt the technologies. For example, DOE estimates that the $4.1 billion investment in solar photovoltaic (PV) technology R&D from 1975 through 2008 accelerated the cost reduction progress by an estimated 12 years, while providing a net economic benefit of $16.5 billion.[1] Some technologies would otherwise be unable to reach commercialization without the participation of the National Labs, particularly if they are left to be developed in the private sector where returns are expected within short time windows.[iv] This is particularly important given the increasing rate of change in the energy industry that is being driven by technology advancements and evolving customer expectations.

Finally, laboratories are uniquely positioned to handle complex, sensitive and/or classified issues of critical importance to the utility industry, such as cybersecurity and resiliency. The research outcomes that the National Labs produce is open sourced to allow utilities to modify and adapt the results.

Today I will highlight three examples of innovation born out of collaboration with the National Labs that has helped Duke Energy ensure our customers have reliable, affordable and increasingly clean energy. These projects have spanned (1) seamlessly integrating renewables, (2) increasing grid resiliency in a distributed energy resource rich future, and (3) increasing the efficiency of fossil generation. While I will talk specifically about these three examples, there are many more contributions from the National Labs that benefit our customers and will help us build a smarter energy future.

Leveraging National Lab Capabilities to Seamlessly Integrate Renewables

With the increasing role that renewables have on the energy grid, Duke Energy recognized a need to improve system planning and operations to seamlessly integrate these intermittent resources and maintain the electric reliability our customers count on. We found our solution by initiating a collaborative partnership with Pacific Northwest National Laboratory (PNNL) beginning in 2012. We conducted four studies with PNNL to understand and manage potential operational and cost impacts of increasing percentages of solar PV production.

The first study simulated the impacts of high rates of solar PV on the grid so that we could operate system infrastructure and particularly our generation portfolio reliably and at the lowest cost to customers. [2] While the project informed system planning and impact on customer rates from increased levels of intermittent renewables, it also helped us to understand how the system would operate in the future so we could revise operational guidelines and identify opportunities

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[1] U.S. Department of Energy. *Revolution ... Now: The Future Arrives for Five Clean Energy Technologies – 2015 Update*. November 2015. Available at: https://www.energy.gov/sites/prod/files/2015/11/f27/Revolution-Now-11132015.pdf

[2] The result of this collaboration was published in 2014 as the Duke Energy Photovoltaic Integration Study: Carolinas Service Areas. Pacific Northwest National Laboratory, Report No. PNNL-23226. Available at: http://www.pnucc.org/sites/default/files/Duke%20Energy%20PV%20Integration%20Study%20201404.pdf

to improve. We dug deeper in a second study with PNNL to evaluate leveraging emerging technologies such as energy storage, smart inverters, and demand side management to most effectively integrate new assets and increase solar generation. This work opened the door for us to rethink how to plan a smarter energy future for our customers.

The National Renewable Energy Laboratory (NREL) further supplemented our understanding of system planning and operational impacts through its Eastern Renewable Generation Integration Study (ERGIS) of the Eastern Interconnection – one of the largest power systems in the world, which spans from central Canada (excluding Québec) eastward to the Atlantic coast, south to Florida and west to the foot of the Rockies (excluding most of Texas). Because of the complexity of the Eastern Interconnection, the unique capabilities of NREL's High Performance Computer (HPC) were critical to this study. The cost of maintaining a HPC for system planning and operations purposes is well outside of even the largest utility's ability. Individual utilities, even partnerships among utilities, would be hard pressed to complete an evaluation this complex both from skill as well as resource availability perspectives. Using high-performance computing and innovative visualization tools, NREL shows the power grid of the eastern United States has the potential to accommodate upward of 30 percent wind and solar/ PV power. These studies are essential to plan for incorporating new technologies and planning the energy grid of tomorrow. Further, it is important for such work to be conducted by unbiased third parties, such as the National Labs, that do not have a commercial interest in the resulting investment portfolio.

Increasing Grid Resiliency with Flexible Distributed Energy Resources

In addition to accommodating greater percentages of intermittent resources like solar, changing weather patterns introduce a new resiliency paradigm for the energy industry. Superstorm Sandy and Hurricane Harvey are providing our industry with real-life indications of how our infrastructure planning will need to evolve in the future. Distributed energy resources (DER) and microgrids will increasingly provide resiliency services during catastrophic events.

Indeed, the electric power industry will continue to evolve as DER and intelligent customer devices are more widely deployed. We must overcome the challenges with today's centralized energy grid, including limitations associated with human monitoring and control of grid resources and aging analog devices, which hamper our ability to integrate high penetrations of renewable energy. Our industry is committed to enhancing grid resiliency and leveraging DER technologies. At Duke Energy, we currently have a proposal under consideration with the Grid Modernization Laboratory Consortium's most recent lab call.[3] The objective of this project is to accelerate the deployment of resilient and secure distribution systems that leverage our traditional distribution assets as well as new DERs and microgrids. While more advanced distribution management solutions are emerging with increasing capabilities, we continue to identify gaps as we work to optimally manage our grid. In the future, it will be critical for the centralized system to be able to coordinate with those decentralized DERs and microgrids that

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[3] "Increasing Distribution System Resiliency using Flexible DER and Microgrid Assets Enabled by OpenFMB" partners include PNNL, NREL, Oak Ridge National Laboratory, GE Grid Solutions, UNC Charlotte, University of Tennessee, Smart Electric Power Alliance and Duke Energy with advisors from Entergy, Avista and North American Energy Standards Board.

are located at the edge of the grid – what we call "grid edge" technologies. Duke Energy is committing $1.2 million over three years to this project, and our hope is to work with the National Labs to deploy "distributed intelligence" that will provide for grid security and interoperability. [4] The results of this project would be applicable to a wide range of technology combinations and all regions of the country. For Duke Energy, this project will inform our grid modernization planning as we work to provide an increasingly reliable and resilient grid to power the lives of our customers.

Improving the efficiency – and affordability – of natural gas generation

Natural gas generation serves a vital role in the power system as dispatchable, flexible capacity to meet electric demand and help manage the intermittency of renewables. Natural gas combined-cycle power plants rely on advanced combustion turbine technology. Today's state-of-the-art "J-class" combustion turbines have an average efficiency of 62.6 percent, but a current project with NETL aims to further improve turbine efficiencies – and thus reduce the amount of fuel needed to produce power. Because fuel savings are passed on dollar for dollar back to electric customers, these projects can lead to a direct benefit of lowering customers' energy bills. The Aerojet Rocketdyne Rotating Detonation Engine (RDE) program, led by NETL, is a perfect example of the need for National Labs to be engaged in long lead-time technologies that support our country's energy future. The program advances combustion turbine technology for combined-cycle applications by integrating a rotating detonation engine (RDE), pressure gain combustion system with an air-breathing power-generating turbine system to reduce energy losses and achieve combined-cycle efficiency up to 68.3 percent. Duke Energy is contributing $150K over three years to demonstrate the technology. A promising early indication is that the advanced turbine design of ongoing operating and maintenance costs are similar to current designs, which would indicate the levelized cost of energy for the RDE plant will be lower than current state-of-the-art combined cycle plants. It is important to note that even high-tech, diverse companies such as Aerojet Rocketdyne are unable to develop these technologies without the commitment of the National Labs.

The Role of the National Labs in Our Energy Future

Our mandate as electric utilities is to provide safe, reliable and affordable energy for customers. Investments in the National Labs enable us to leverage new technologies to modernize the power grid and stimulate economic growth while continuing to meet this mandate. As a result of the National Labs' work, all electric customers benefit from the R&D that advances electric power infrastructure, cleaner energy solutions and more efficient technologies. However, if we were to privatize energy R&D, then technology development will be driven by a singular goal or financial return, and the end result is unlikely to benefit all citizens.

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[4] Distributed Intelligence (DI) is an architecture that supports building layered intelligence on the grid to enable a multifunction and integrated distributed grid management systems. With the ability to enhance utilities' capability to monitor and control the flow of electricity, to seamlessly integrate with DERs, and to easily scale to handle millions (and potentially billions) of discrete data points in a secure, timely and cost-effective manner, DI offers great promise to aid the electric utility industry to meet the safety, efficiency, reliability and environmental requirements of the 21st century.

Reliable and affordable energy access has become a customer expectation in the United States – and it is the engine for economic development. The energy grid is the highway that delivers that energy to our communities, and we must continue to invest in that highway infrastructure to keep our economy moving. The National Labs and publicly funded research ensures that electric customers will benefit from the modernization of our energy infrastructure.

The energy sector is going through an exciting and important transformation. We're seeing a powerful convergence of trends in energy technologies, telecom & IT, coupled with changing customer expectations, public policies and business models. To secure a stronger energy future for our customers and communities, we must anticipate and adapt to these changes. As we look to the future, we believe the National Labs and the public-private collaborations through DOE, ARPA-E and other partnerships are critical. The suite of capabilities offered by the National Labs are unattainable anywhere else in the industry and are critical to the industry's ability to understand how to better operate and plan our system for the future. This ultimately ensures electric customers and our communities have the lowest cost, most reliable, resilient, and advanced clean energy system in the world.

Thank you for the opportunity to be here today and I look forward to your questions.

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[i] At Duke Energy, our emerging technology team spends time monitoring trends and industry activity to track technology developments and consider the best time to adopt and deploy new technologies. We focus on:

- Maturation: We work hard to ensure technology moves into a lab test or pilot and ultimately into our operations at the right time in their technology maturation process.
- Utility-scale: Sometimes a technology may be commercially ready, and there's more than one unit out there, but we're still monitoring market acceptance. We really want a technology to be utility grade; that's when we're ready to take it to scale and deploy across our system.
- Customer need: Finally, the most important criterion we evaluate when deploying a new technology is simple – it must deliver value to the customer. Otherwise, it's just technology for technology's sake.

[ii] New technologies pass through several stages on the path to commercialization:

1. Innovation Trigger: A breakthrough, public demonstration, technology/product launch, or some other event generates press and industry interest in a technology innovation. These innovations and discoveries are simply too complex and have too large an inherent risk for any single private enterprise to undertake. The National Labs are often engaged in these breakthroughs, with utilities serving as advisors.
2. Peak of Inflated Expectations: A wave of "buzz" builds and the expectations for this new technology rise above the current reality of its capabilities. In some cases, an investment bubble forms. The National Labs continue to work on these efforts. Startups will begin to emerge that look to capitalize on the excitement. Emerging Technology teams, like ours at Duke Energy, begin early testing to confirm or refute the technological claims.
3. Trough of Disillusionment: Inevitably, impatience for results begins to replace the original excitement about potential value. Problems with performance, slower-than-expected adoption or a failure to deliver financial returns in the time anticipated all lead to missed expectations, and disillusionment sets in. The private sector, VCs, and those early startups will divest and move on to other promising technologies. We must rely on DOE, National Labs and ARPA-E to continue to advance promising technologies through this challenging period. Utilities will look to partner with these organizations to better understand the capabilities and possibilities for the future.
4. Slope of Enlightenment: Some early adopters overcome the initial hurdles, begin to experience benefits and recommit efforts to move forward. Drawing on the experience of the early adopters, understanding grows about where and how the technology can be used and, just as importantly, where it delivers little or no value. Utilities may begin developing pilots and conducting pre-scale deployments as we evaluate the best-use cases and applications for new technologies that bring the most value to our customers.

5. Plateau of Productivity: With the real-world benefits of the technology demonstrated and accepted, growing numbers of organizations feel comfortable with the now greatly reduced levels of risk. A sharp uptick in adoption begins, and penetration accelerates rapidly as a result of productive and useful value. This is when you really see the utility industry start adopting – once the product and financial risk has been mitigated, there are clear use cases for adoption and demonstrated value for the customer.

[iii] Drastic reductions in the cost of wind energy are, in part, a result of the $2.4 billion invested by the DOE in wind R&D between 1976 and 2014, which has enabled many key innovations such as the taller turbines, longer blades, and improved electronics. Public-private partnerships R&D investments have also been critical in bringing down costs for LED lighting by 90 percent since 2008.

[iv] Historically, cleantech companies have been more likely to fail and offer lower returns relative to software companies. Since 2007, only 13 American series A cleantech firms exited at over $500M valuations.

Senator GARDNER. Thank you, Ms. Ratnayake.

Dr. Kearns, as introduced by Senator Duckworth, the Interim Director at the Argonne National Laboratory.

Thank you.

STATEMENT OF DR. PAUL KEARNS, INTERIM LABORATORY DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. KEARNS. Chairman Gardner, Ranking Member Manchin and members of the Subcommittee, thank you for the opportunity to appear before you today.

I am Paul Kearns, the Interim Director of Argonne National Laboratory which is located in Lemont, Illinois. For nearly three decades I've held senior management positions in the Department of Energy's national laboratories. I am passionate about securing our nation and encouraging breakthrough discoveries in science and technology.

For more than 70 years the U.S. Department of Energy and its national laboratories have been delivering scientific discovery and innovation focused on understanding nature's deepest secrets, improving the way our nation generates, distributes and uses energy, and enhancing global, national and our homeland security. Time and again the laboratories have been called upon to overcome the world's greatest scientific challenges, from answering urgent questions about outbreaks of Ebola to mitigating weather-related risk with innovative detailed computer models.

The Department of Energy operates five light sources, including our Advanced Photon Source at Argonne. Each offers a different way of characterizing materials at the atomic and molecular level so that we may understand, predict and ultimately control material properties.

From these facilities come life-changing discoveries. Drugs used to treat and halt the progression of conditions, including advanced kidney cancer, malignant and inoperable skin cancer, a common type of leukemia and HIV all got their start at Argonne's Advanced Photon Source. Research there has also led to greater understanding of diseases ranging from autism to osteoporosis.

This ability to view matter in great detail has led to many other inventions as well. The intense x-rays of the Argonne Advanced Photon source has helped us design the technology that's used in the battery cell that powers the Chevy Volt. It has also led to insights about how to improve the reliability of additive manufacturing, the efficiency of the internal combustion engines and the possibility of hypersonic flight. These insights flow from open and productive partnerships with a range of industries including pharmaceuticals, oil and gas and transportation.

As we upgrade Argonne's Advanced Photon Source, researchers will be able to peer deeper in near real time and develop, for example, next generation quantum materials with extraordinary properties and create 3-D images of the human brain. In other words, the ultimate 3-D microscope is within the nation's grasp.

More than 30 of the 500 fastest supercomputers in the world can be found at DOE laboratories. At Argonne, we've helped industry perform simulations in support of more efficient jet engines and wind turbines and help doctors arrive at prognosis and treatment plans designed specifically for individual cancer patients. Scientists also use these resources to enhance the creation of nanocircuits to usher in the next generation of electronic circuitry.

We design, build and operate distinctive scientific instrumentation and facilities making supercomputing, imaging and other resources available to the wider research community. This multiplies the value the national laboratories deliver through collaboration with more than 30,000 users of our facilities from academia and industry.

With our unique talent and tools, national laboratories play a critical role in large-scale, long-term research and development that compliments the pursuits of universities and industry to discover new knowledge and better human lives.

Argonne's material science and chemistry research has yielded a spectrum of innovations ranging from some of the toughest ceramic ever produced—perfect for energy and transportation applications—to innovations that demonstrate the doubling of the carrying capacity of the best commercial superconductors.

DOE laboratories and universities mutually benefit from developing strategic partnerships. These partnerships capitalize on the different strengths of their respective organizations and bring unique solutions to regional and broad national challenges.

As an example, the Institute for Molecular Engineering created, as a partnership between Argonne and its parent organization, the University of Chicago, looks to impact major society issues with innovative technologies achieved through molecular scale, design and manipulation.

The Argonne Joint Center for Energy Storage Research, JCESR, DOE's battery and energy storage hub, is an example of a successful public-private partnership, bringing together collaborators from universities, industry, and other national laboratories. The hub's mission is to look beyond lithium ion, today's technology, to create next generation battery technologies that will transform the transportation sector and the electrical grid, the way today's lithium ion batteries have transformed personal electronics.

In addition to energy storage, national laboratories are working to create a more reliable and resilient power infrastructure for U.S. energy and economic security, as has been mentioned already today. The laboratories increase the mobility of our citizens with new transportation systems through diversified fuel sources and increased efficiency.

We integrate combustion, fuels and lightweight materials research to improve internal combustion engine efficiency. We explore the possibility of cost-effective and durable hydrogen storage materials for fuel cells and develop and deploy new energy storage technologies for electric and hybrid electric vehicles.

Specialists in backgrounds in engine and combustion system development, as well as high-octane and bio-derived fuel chemistries collaborate with our leading experts in advanced engine simulations allowing for comprehensive assessment of alternative fuels to optimize fuel economy gains for a range of applications.

National laboratories make us more secure by advancing nuclear materials management, detection, and forensic capabilities to protect the nation. They also enhance the safety, security and reliability of the nation's nuclear deterrent. We provide the targeted, sophisticated data collection and lightning-paced parsing necessary to inform national security decision-making, and create an advantage with energy and power solutions specifically designed to fulfill national security missions.

The success of the national laboratories is being noticed by other countries. They are looking at our model to replicate its unique interdisciplinary nature. We must continue to invest in this system to remain at the forefront of research and development as we overcome the greatest scientific challenges.

Thank you for your time and interest in how the national laboratories bring greater security, health, and prosperity to Americans.

I welcome any questions that you might have.

[The prepared statement of Dr. Kearns follows:]

Written Testimony of Dr. Paul Kearns
Interim Laboratory Director, Argonne National Laboratory
before the
Subcommittee on Energy of the
U.S. Senate Committee on Energy & Natural Resources
September 12, 2017

Chairman Gardner and Ranking Member Manchin, and members of the subcommittee, thank you for the opportunity to appear before you today.

I am Paul Kearns, interim director of Argonne National Laboratory, one of America's first and largest multipurpose science and engineering laboratories, located in Lemont, Illinois. Before becoming Argonne's interim director in January 2017, I served as Argonne's Chief Operations Officer and prior to Argonne, I held leadership positions at Battelle Global Laboratory Operations, Idaho National Engineering and Environmental Laboratory, and Pacific Northwest National Laboratory. I also served as a visiting professor in engineering and physical sciences at the University of Manchester in the United Kingdom.

As you can see, I have devoted much of my career to expanding the national laboratories' unique mission of securing our nation and encouraging break-through discoveries in science and technology. It was the special mission of the laboratories that attracted me to the national laboratory system and it is the opportunity to work with such dedicated and talented people, on things that matter, that has kept me involved with the national laboratories.

For more than 70 years, the U.S. Department of Energy and its national laboratories have improved the way our nation generates, distributes, and uses energy. Time and again, the laboratories have been called upon to overcome the world's greatest scientific challenges. Working together to solve national challenges, the national laboratories bring to bear decades of expertise from researchers in physics, materials and chemistry, math and computer science, life sciences, nuclear energy and more.

This network of 17 national laboratories is a vital component of the science and innovation ecosystem of the United States with major continuing impact. It encompasses multipurpose science and security laboratories, as well as single purpose laboratories related to specific science and technology aims. Focusing on the core missions, dynamic programs and rapid response needs of the country allows the system to address major science programs and respond to needs such as answering urgent questions about outbreaks of Ebola in Africa and mitigating weather-related risks with innovative, detailed computer models.

For example, the DOE operates five light sources - the Advanced Light Source at Lawrence Berkeley National Laboratory, the National Synchrotron Light Source at Brookhaven National Laboratory, the Stanford Synchrotron Radiation Lightsource and Linac Coherent Light Source at the Stanford Linear Accelerator Center, and the Advanced Photon Source at Argonne National Laboratory. Each offers a different way of characterizing materials at the atomic and molecular level so that we may understand, predict, and ultimately control materials properties. These facilities generate both hard X-rays that penetrate nearly any surface to reveal the inner workings of materials and technologies as well as soft X-rays that are less intrusive.

Similarly, DOE also operates five nanoscale science research centers, strategically located within national laboratories across the country. Each center has particular expertise and capabilities in selected theme areas, with the goal of understanding, predicting, and ultimately controlling matter and energy at the atomic scale. This research provides the foundation for future new technologies and supports the DOE mission in energy, environment, and national security.

From these facilities come life-changing discoveries. Drugs used to treat and halt the progression of conditions including advanced kidney cancer, malignant and inoperable skin cancer, a common type of leukemia, and HIV all got their start at Argonne's Advanced Photon Source. Research there also has led to greater understanding of diseases ranging from autism to osteoporosis.

This ability to view matter in great detail has led to other innovations as well—the intense X-rays of the Advanced Photon Source helped Argonne design the technology used in the battery cell that powers the Chevy Volt. It has also led to insights about how to improve the reliability of additive manufacturing, the efficiency of internal combustion engines, and the possibility of hypersonic flight. These insights flow from open and productive partnerships with a range of industries, including pharmaceuticals, oil and gas, and transportation.

As we update Argonne's Advanced Photon Source, researchers will be able to peer deeper and develop, for example, 3-D images of the entire human brain, building upon current neuroscience research that has developed models of a mouse's brain. In other words, the ultimate 3-D microscope is within Argonne's grasp.

Breakthroughs such as this highlight many other strengths of the laboratories as well. For example, Argonne's interdisciplinary culture combines the imaging of the Advanced Photon Source with deep and broad materials science expertise and modeling capabilities of the Argonne Leadership Computing Facility.

More than 30 of the 500 fastest supercomputers in the world can be found at DOE laboratories. Like our light sources, these high-performance computing facilities offer an unparalleled combination of resources, which is helping scientists accelerate their research in many fields, enabling high-impact scientific discoveries, and making a transformative impact on society. At Argonne we have helped industry perform simulations in pursuit of more efficient jet engines and wind turbines, and now we are working to combine new capabilities in machine learning with novel data acquisition and analysis techniques and simulations to help doctors arrive at prognosis and treatment plans designed specifically for individual cancer patients. Scientists are also using these resources to enhance the creation of nanocircuits to usher in the next generation of electronic circuitry.

The national laboratories make these large-scale, powerful facilities and their specialists available to a community of more than 30,000 researchers from all 50 states annually from industry, academia, and other national laboratories.

None of what the national laboratories accomplish would be possible without highly skilled and visionary researchers. World-class researchers who work at the national laboratories keep our nation secure and economically competitive.

We design, build, and operate distinctive scientific instrumentation and facilities, making supercomputing, imaging, and other resources available to the wider research community. This impact multiplies as we collaborate with more than 30,000 users of our facilities, combined with nearly 60,000 scientists, engineers, and employees across the Department of Energy's national laboratory complex. With our unique talent and tools, national laboratories play a critical role in large-scale, long-term research and development that complements the pursuits of universities and industry to discover new knowledge and better human lives.

Argonne's materials science and chemistry research has yielded a spectrum of innovations ranging from some of the toughest ceramic ever produced—perfect for energy and transportation applications—to smart, highly insulated windows that could save 5 percent of the nation's energy budget.

Elevating our accomplishments is the constellation of relationships the national laboratories have with other researchers. Partnerships mutually benefit the DOE laboratories and universities—from single collaborations between principal investigators to long-term, interdisciplinary scientific programs leveraging multiple resources in talent, facilities, and ideas. These partnerships capitalize on the different strengths of the respective organizations and bring unique solutions to regional and broad national challenges. As an example, the Institute for Molecular Engineering, created as partnership between Argonne and its parent organization, the University of Chicago, looks to impact major society issues with innovative technologies achieved through molecular-scale design and manipulation.

Universities make up a third of the partner organizations in the Argonne-led Joint Center for Energy Storage Research (JCESR), DOE's battery and energy storage hub, with many others serving as affiliates and collaborators. The hub's mission is to create next-generation battery technologies that will transform the transportation sector and the electric grid the way lithium-ion batteries transformed personal electronics. JCESR is an example of a successful public-private partnership, bringing together collaborators from universities, industry, and other national laboratories.

In addition to energy storage, national laboratories are working to create a more reliable and resilient power infrastructure for U.S. energy and economic security. We are using such solutions as grid-scale storage to take full advantage of intermittent resources and we are empowering consumers to manage more of their consumption via smart appliances, smart meters, and transparent pricing. In collaboration with local utilities and first responders, national laboratories have developed technologies such as self-healing frameworks to mitigate the consequences of cyber-attacks and advanced sensor technologies to aid in physical security of the electric grid and our infrastructure.

Our breakthrough science and engineering accomplishments are rolling back the frontiers of discovery in many areas.

The laboratories increase the mobility of our citizens with new transportation systems to diversify fuel sources and increase efficiency. We integrate combustion, fuels, and lightweight materials research and development to improve internal combustion engine efficiency, and develop and deploy new energy storage technologies for electric and hybrid-electric vehicles.

National laboratories make us all more secure by advancing nuclear materials management, detection, and forensics capabilities to protect the nation. They also enhance the safety, security, and reliability of the nation's nuclear deterrent. We provide the targeted, sophisticated data collection and lightning-paced parsing necessary to inform national security decision-making, and create an advantage with energy and power solutions specially designed to fulfill national security missions.

Our researchers contribute to the greater health of our nation by increasing the understanding of diseases in order to fight them more effectively. Argonne scientists were part of a team that determined the 3-D atomic structures of more than 1,000 proteins and deposited their findings into World-Wide Protein Data Bank. National laboratories are melding medical research and high-performance computing to create precise therapy options based on genetics.

Underpinning all these goals is the fact that the national laboratories are equipped like none other to expand our fundamental understanding of matter, materials, and their properties. With world-leading X-ray sources, particle accelerators, supercomputers, nanoscale science centers, and other facilities, we conduct basic research across the spectrum from the large-scale structure of our universe to the microscopic nature of matter at subatomic levels. We discover new materials and chemical assemblies and apply their novel structures, functions, and properties to new ways of generating, distributing, and using energy.

The success of the national laboratory system is being noticed by other countries that are looking at our model to replicate its unique interdisciplinary culture. We must continue to invest in this system to remain at the forefront of research and development as we overcome the greatest scientific challenges.

Thank you for your time and your interest in how the national laboratories bring greater security, health, and prosperity to Americans. The decades of time national laboratories have invested, combined with our world-class talent and one-of-a-kind tools, enables us to excel in large-scale, research and development challenges that complement those of universities and industry, to explore new frontiers of knowledge and elevate the well-being of society. I welcome any questions that you might have.

Senator GARDNER. Thank you, Dr. Kearns.

Dr. Anderson, introduced by Senator Manchin, the Director of the West Virginia Energy Institute.

Thank you, Dr. Anderson.

STATEMENT OF DR. BRIAN J. ANDERSON, DIRECTOR OF THE WVU ENERGY INSTITUTE, WEST VIRGINIA UNIVERSITY

Dr. ANDERSON. Chair Gardner and the rest of the Committee, I thank you very much for your attention today. And I do, certainly, thank Senator Manchin for his kind introduction.

As he mentioned, I am the Director of the WVU Energy Institute at West Virginia University. We are the central umbrella organization to help coordinate interdisciplinary and multidisciplinary research across our 14 colleges and schools and that includes 167 affiliate faculty members who work in the energy space.

I am the GE Plastics Materials Engineering Professor of Chemical Engineering and have 17 years of energy research experience, primarily in chemical engineering, CO2 sequestration, natural gas hydrates, unconventional gas production and geothermal energy. In all of these research areas I have personally collaborated with NREL, Argonne, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Idaho National Lab and, of course, NETL.

West Virginia University is a public, land-grant, research-intensive university. It is one of the Carnegie Classification Research 1 universities, which is the top 115 universities performing research in the country.

Our Morgantown campus hosts the University Energy Institute, the National Research Center for Coal and Energy, the Center for Alternative Fuels, Engines and Emissions which discovered the Volkswagen was cheating on their emissions tests last year.

The University has active and ongoing research related to operating improvements on existing coal-fired power generation, the recovery of rare earth elements from coal wastes, instrumentation and sensor development to accurately measure fugitive emissions from shale gas wells, analysis of sub-surface geologic structures and their applicability to store gas liquids, carbon sequestration or to produce natural gas.

We have also developed sophisticated software systems and algorithms that can model complex fossil fuel combustion systems, as well as complex electric transmission grids responding to variable generation from intermittent sources like solar and wind.

In the renewable space, we are a leader in biomass as well as geothermal energy and in energy storage to enable renewable energy technologies onto the grid.

Additionally, the U.S.-China Clean Energy Research Center (CERC) Advanced Coal Technology Consortium is based in the WVU Energy Institute at West Virginia University. That consortium is one of five consortia across the country that was created through a bi-lateral protocol signed in 2009 between the United States Department of Energy and two agencies of the People's Republic of China, the Ministry of Science and Technology and the National Energy Administration. The initial phase of this Center's Protocol spanned five years and in 2015 was extended another five years.

As with most of our major research initiatives at WVU, this CERC program involves a number of Department of Energy National Laboratory collaborations. The CERC program has national laboratory project partners, such as Lawrence Livermore National Laboratory, Los Alamos National Lab, the National Energy Technology Laboratory. And these lab partners are in addition to the number of private sector and academic institutions including Duke Energy.

A second project that I would draw your attention to is called the Marcellus Shale Energy Environment Laboratory (MSEEL). Again, this is a collaboration between the National Energy Technology Lab and WVU.

As we know, much of our power sector is shifting to natural gas and a lot of natural gas is being produced from Appalachia. Our MSEEL site is the world's first transparent well in the sense that all the data collected in terms of its water footprint, its air footprint, noise, light and the full cycle of the production of natural gas from the Marcellus Shale site in Morgantown is open to the public.

This is one of the most instrumented wells in the world and we have a full record of all of the emissions through the cycle with the design on reducing emissions during production as well as emissions during transportation and distribution of natural gas. Not only is this project funded by the DOE Fossil Program, it does heavily involve NETL as a research partner.

In addition to the partnership between CERC and MSEEL, the University has active relationships with the NREL in geothermal, biomass and hydroelectric, Brookhaven National Lab, Oak Ridge, Pacific Northwest and Lawrence Berkeley National Lab, not to leave them out, but these are our major research collaborations.

We have worked with NETL since 1946 supporting their R&D activities. In '46 the research came to Morgantown in the form of a synthesis gas branch experiment station, specifically focused on coal gasification research at WVU.

WVU has collaborated with the NETL when it was the Morgantown Energy Center. The Morgantown Energy Technology Center, the Federal Energy Technology Center and, of course, now, NETL.

So for the better part of the last decade we have, through the onsite research contract, been a part of the Regional University Alliance with our partners at Carnegie Mellon University, the University of Pittsburgh, Virginia Tech and Penn State, where many students have completed their Ph.D. work onsite at the laboratory, including many of my own. Not only does this provide a broad and talented research workforce for the laboratory, but it also has resulted in a number of R&D 100 awards that have been awarded to RUA researchers.

So generally, innovation ecosystems often include innovation clusters at the scale of metropolitan areas that form a core research group of universities or companies. These innovation clusters are typically driven by the interaction of early stage technology ideas or firms with financing and related companies in a geographically concentrated area that has an enabling environment.

Geographic proximity often encourages rapid commercialization; however, the DOE national laboratories act not only as a convening party, but that catalyst in a hub for innovation ecosystems across the United States.

I do sincerely thank the Committee for your time and attention today and for allowing me to speak about West Virginia University and our partnerships with the many national laboratories.

Thank you.

[The prepared statement of Dr. Anderson follows:]

Brian J. Anderson, Director of the WVU Energy Institute, West Virginia University

Written Testimony of Brian J. Anderson to the Senate Committee on Energy and Natural Resources' Subcommittee on Energy

September 12, 2017

Chair Gardner, Ranking Member Manchin and members of the Subcommittee, thank you for the opportunity to offer relevant testimony and to answer your questions in my areas of experience and expertise.

I am the Director of the WVU Energy Institute at West Virginia University in Morgantown, West Virginia. The WVU Energy Institute is the central organization on the West Virginia University campus with a mission to coordinate cross- and multi-disciplinary research across our 14 schools and colleges in energy as well as working with the state of West Virginia to stimulate economic development while utilizing our energy resources responsibly. The West Virginia University Energy Institute has 167 affiliate faculty members across many different areas of research in the university. In addition to my role as director, I am the GE Plastics Materials Engineering Professor of Chemical Engineering and have 17 years of energy research experience primarily in chemical engineering and in subsurface science as related to CO_2 sequestration, natural gas hydrates, unconventional gas production, and geothermal energy.

West Virginia University is a public, land-grant, research-intensive university founded in 1867. It is designated an "R1" Research University (Very High Research Activity) by the Carnegie Foundation for the Advancement of Teaching; funding for sponsored research programs exceeds $170 million. The Morgantown campus houses the West Virginia University Energy Institute, the National Research Center for Coal and Energy, and the Center for Alternative Fuels, Engines and Emissions which discovered the Volkswagen diesel engine emissions software installation that allowed its diesel engines, in test mode, to meet emissions compliance standards, but to operate out of compliance when not in test mode.

The university has active and ongoing research related to operating improvements on existing coal-fired power generation, the recovery of rare earth elements from coal wastes, instrumentation and sensor development to accurately measure fugitive emissions from shale gas wells, analysis of sub-surface geological structures and their applicability to store gas liquids, store carbon or produce gas. The university also has developed sophisticated software and algorithms that can model complex fossil fuel combustion systems, as well as complex electric transmission grids responding to variable generation from intermittent sources like solar and wind. In the renewable space, we are a leader in biomass as well as geothermal and in energy storage to enable renewable energy technologies into the grid.

Additionally, the U.S.-China Clean Energy Research Center Advanced Coal Technology Consortium (CERC-ACTC) is based in the WVU Energy Institute at West Virginia University in Morgantown, West Virginia. The consortium is one of five consortia that were created through a bi-lateral Protocol signed in 2009 between the United States Department of Energy and two agencies of the People's Republic of China: the Ministry of Science and Technology and the National Energy Administration. The initial phase of Center's Protocol spanned five years (2011-2015) and in 2015 was extended an additional five years (2016-2020) under the direction of Jim Wood.

Most of our major research initiatives at WVU involve U.S. Department of Energy National Laboratory collaborations. The CERC-ACTC has as national laboratory project partners Lawrence Livermore National

Laboratory, Los Alamos National Laboratory, and the National Energy Technology Laboratory. These lab partners are in addition to a number of private sector and academic institutions in the U.S.

A second project that I do want to draw attention to is called the Marcellus Shale Energy Environment Laboratory. As we know, much of our power sector is shifting to natural gas and there's a lot of natural gas and natural gas liquids being produced from the region in Appalachia. Our Marcellus Shale Energy Environment Laboratory called MSEEL is the world's first transparent well in the sense that all the data collected in terms of its water footprint, its air footprint, noise, light and the full cycle of the production of natural gas from this Marcellus Shale site in Morgantown is open to the public. This is one of the most instrumented wells in the world and we have a full record of all of its emissions through the cycle with the design on reducing emissions during production as well as emissions during transportation and distribution of natural gas. This project is not only funded by the DOE Fossil Energy Program, but the National Energy Technology Laboratory is an active research partner.

In addition to the partnership on CERC-ACTC that includes the National Energy Technology Laboratory, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory, WVU has active relationships with the National Renewable Energy Laboratory (geothermal, biomass, hydroelectric), Brookhaven (catalysis and chemistry), Oak Ridge National Laboratory (manufacturing and materials), Pacific Northwest National Laboratory (gas hydrates, catalysis, materials, and reaction chemistry), and Lawrence Berkeley National Laboratory (gas hydrates, geothermal, and geosciences).

West Virginia University has worked with NETL or its precursor laboratories since 1946 supporting NETL's R&D efforts. In 1946, research came to Morgantown in the form of the Synthesis Gas Branch Experiment Station, exploring coal-gasification research at WVU. WVU has collaborated with the NETL as the Morgantown Energy Center, the Morgantown Energy Technology Center, the Federal Energy Technology Center, and since 1999, the National Energy Technology Center. West Virginia University is currently supporting all five core competency research directorates: Computational Science and Engineering, Energy Conversion Engineering, Materials Engineering and Manufacturing, Geological and Environmental Systems, and Systems Engineering and Analysis. West Virginia University brings expertise to the LRST in many of the programmatic areas including: Rare Earth Elements, Energy Systems, Carbon Capture, Carbon Storage, Natural Gas Resources, Methane Hydrates, EOR, and Natural Gas Infrastructure.

For the better part of the last decade, WVU has, through the on-site Research and Engineering Services (RES) contract, been a part of the NETL-Regional University Alliance (RUA). This vehicle provided a formal mechanism for direct collaboration on-site between the member universities (West Virginia University, University of Pittsburgh, Carnegie Mellon University, Penn State University, and Virginia Tech) and the NETL. Many of my own students have completed the bulk of their PhD dissertation work at or in direct collaboration with the NETL. Not only does this provide a broad and talented research workforce at the fingertips of the NETL, but has directly resulted in a number of R&D 100 awards and commercial technologies.

Generally, innovation ecosystems often include innovation clusters at the scale of a metropolitan area from a core group of research universities or companies. These innovation clusters are typically driven by the interaction of early stage technology ideas or firms with financing and related companies in a geographically concentrated area that has an enabling environment (e.g. supportive state policies and market pull). Geographic proximity encourages rapid commercialization through increased communication and collaboration among the organizations. The DOE National Laboratories act as not only a convening party but a catalyst and a hub for innovation ecosystems across the United States.

I sincerely thank the committee for their time and attention today and for allowing me to speak about West Virginia University's experience with the National Laboratories and their role in fostering innovation.

Brian J. Anderson
Director, WVU Energy Institute
GE Plastics Materials Engineering Professor of Chemical Engineering
West Virginia University, Morgantown, WV
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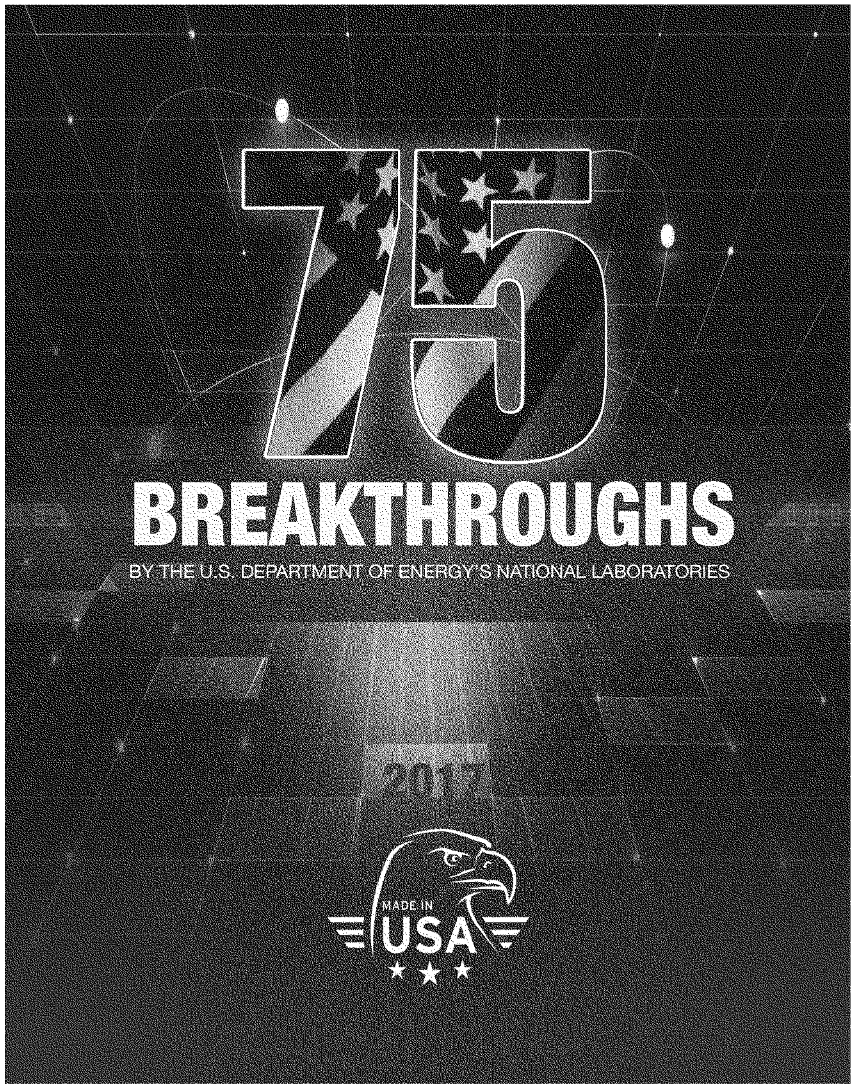
304-293-6631

Senator GARDNER. Thank you, Dr. Anderson, and thanks to all of you for being here, again, today.

I think this panel is a great representation of what our national labs stand for and how research and development in this country really works because we have not only the scientists from our great laboratories across the country, but we have the private sector involvement, we have our universities and research institutions that are all at the table to talk about innovations in research science and how we are going to maintain, in this country, the leading edge of innovation.

I encourage everybody who is listening or a part of this on the dais to check out this "Breakthroughs" by America's national laboratories, 75 breakthroughs, the highlights in 2017.

[The information referred to follows:]


75
BREAKTHROUGHS
BY THE U.S. DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES
2017
MADE IN
USA

75 BREAKTHROUGHS

By America's National Laboratories

U.S. DEPARTMENT OF ENERGY

AMES LABORATORY

Argonne NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

Fermilab

INL Idaho National Laboratory

Jefferson Lab Thomas Jefferson National Accelerator Facility

Berkeley Lab Lawrence Berkeley National Laboratory

Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY

NATIONAL ENERGY TECHNOLOGY LABORATORY

NREL

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Sandia National Laboratories

SLAC NATIONAL ACCELERATOR LABORATORY

SRNL

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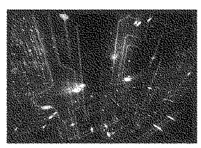
AMERICA'S NATIONAL LABORATORIES . . .

have been changing and improving the lives of millions of people for more than 75 years. Born at a time when the world faced a dire threat, the laboratories came together to advance science, safeguard the nation and protect our freedoms for generations to come. This network of Department of Energy Laboratories has grown into 17 facilities, working together as engines of prosperity and invention. As this list of breakthroughs attests, Laboratory discoveries have spawned industries, saved lives, generated new products, fired the imagination and helped to reveal the secrets of the universe. Rooted in the need to serve the public good and support the global community, the National Laboratories have put an American stamp on the last century of science. With equal ingenuity and tenacity, they are now engaged in innovating the future.

At America's National Laboratories, we've. . .

Advanced supercomputing

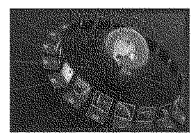


The National Labs operate some of the most significant high performance computing resources available, including 32 of the 500 fastest supercomputers in the world. These systems, working at quadrillions of operations per second, model and simulate complex, dynamic systems – such as the nuclear deterrent – that would be too expensive, impractical or impossible to physically demonstrate. Supercomputers are changing the way scientists explore the evolution of our universe, climate change, biological systems, weather forecasting and even renewable energy.

Decoded DNA

In 1990, the National Labs joined with the National Institutes of Health and other laboratories to kick off the Human Genome Project, an international collaboration to identify and map all of the genes of the human genome.

Brought the web to the United States

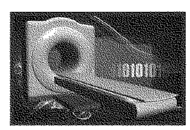


National Lab scientists, seeking to share particle physics information, were first to install a web server in North America, kick-starting the development of the worldwide web as we know it.

Put eyes in the sky

Vela satellites, first launched in 1963 to detect potential nuclear detonations, transformed the nascent U.S. space program. The satellites featured optical sensors and data processing, logic and power subsystems designed and created by National Labs.

Revolutionized medical diagnostics and treatment



Researchers at the National Labs helped to develop the field of nuclear medicine, producing radioisotopes to diagnose and treat disease, designing imaging technology to detect cancer and developing software to target tumors while sparing healthy tissue.

Powered NASA spacecraft

The National Labs built the enclosure for the radioisotope thermoelectric generators that fuel crafts such as Cassini and have begun producing plutonium-238 for future NASA missions.

Harnessed the power of the atom

National Lab scientists and engineers have led the world in developing safe, efficient and emissions-free nuclear power. Starting with the first nuclear reactor to generate electricity, National Labs have been the innovation engine behind the peaceful use of nuclear energy. Today's labs are supporting the next generation of nuclear power that will be available for the nation and world.

Brought safe water to millions

Removing arsenic from drinking water is a global priority. A long-lasting particle engineered at a National Lab can now do exactly that, making contaminated water safe to drink. Another technology developed at a National Lab uses ultraviolet light to kill water-borne bacteria that cause dysentery, thus reducing child mortality in the developing world.

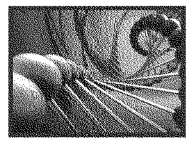
Filled the Protein Data Bank

National Lab X-ray facilities have contributed a large portion of more than 100,000 protein structures in the Protein Data Bank. A protein's structure reveals how it functions, helping scientists understand how living things work and develop treatments for disease. Almost all new medications that hit the market start with these data bank structures.

Invented new materials

National Labs provide the theory, tools and techniques that offer industry revolutionary materials such as strong, lighter-weight metals and alloys that save fuel and maintenance costs and enable cleaner, more efficient engines.

Found life's mystery messenger

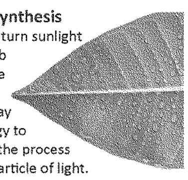


National Lab scientists discovered how genetic instructions are carried to the cell's protein manufacturing center, where all of life's processes begin. Subsequent light source research on the genetic courier, called messenger RNA, has revealed how the information is transcribed and how mistakes can cause cancer and birth defects.

Mapped the universe — and the dark side of the moon

Credit for producing 3D maps of the sky — and 400 million celestial objects — goes to National Lab scientists, who also developed a camera that mapped the entire surface of the moon.

Shed light on photosynthesis



Ever wonder how plants turn sunlight into energy? National Lab scientists determined the path of carbon through photosynthesis, and today use X-ray laser technology to reveal how each step in the process is triggered by a single particle of light. This work helps scientists explore new ways to get sustainable energy from the sun.

Solved cultural mysteries

The works of ancient mathematician Archimedes — written over by medieval monks and lost for millennia — were revealed to modern eyes thanks to the X-ray vision and light-source technology at National

Labs. These studies also have revealed secrets of masterpiece paintings, ancient Greek vases and other priceless cultural artifacts.

Revolutionized accelerators

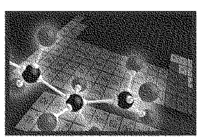
A National Lab built and operated the first large-scale accelerator based on superconducting radio frequency technology. This more efficient technology now powers research machines for exploring the heart of matter, examining the properties of materials and providing unique information about the building blocks of life.

Revealed the secrets of matter

Protons and neutrons were once thought to be indivisible. National Lab scientists discovered that protons and neutrons were made of even smaller parts, called quarks. Over time, experimenters identified six kinds of quarks, three types of neutrinos and the Higgs particle, changing our view of how the material world works.

Confirmed the Big Bang and discovered dark energy

National Lab detectors aboard a NASA satellite revealed the birth of galaxies in the echoes of the Big Bang. Dark energy — the mysterious something that makes up three-quarters of the universe and causes it to expand at an accelerating rate — also was discovered by National Lab cosmologists.



Discovered 22 elements

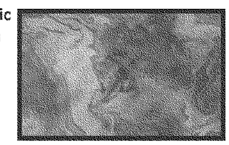
The periodic table would be smaller without the National Labs. To date the National Labs have discovered: technetium, promethium, astatine, neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, lawrencium, rutherfordium, dubnium, seaborgium, flerovium, moscovium, livermorium, tennessine and oganesson.

Made refrigerators cool

Next-generation refrigerators will likely put the freeze on harmful chemical coolants in favor of an environmentally friendly alloy, thanks to National Lab scientists.

Got the lead out

Removing hazardous lead-based solders from the environment is a reality thanks to a lead-free alloy of tin-silver-copper developed at a National Lab. The lead-free solder has been licensed by more than 60 companies worldwide.



Invented a magic sponge to clean up oil spills

National Lab scientists used a nano technique to invent a new sponge that can absorb 90 times its own weight in oil from water. It can be wrung out to collect the oil and reused hundreds of times — and it can collect oil that has sunk below the surface, something previous technology couldn't do.

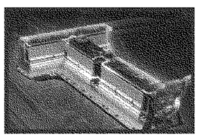
Added the punch to additive manufacturing

High-pressure gas atomization processing pioneered at a National Lab made possible the production of titanium and other metal-alloy powders used in additive manufacturing and powder metallurgy.

Created inexpensive catalysts

Low-cost catalysts are key to efficient biomass refining. National Lab scientists created catalysts that are inexpensive and stable for biomass conversion.

Created high-tech coatings to reduce friction
National Lab scientists created ways to reduce wear and tear in machines from table fans to car engines all the way up to giant wind turbines, such as a diamond-like film that rebuilds itself as soon as it begins to break down — so that engines last longer and need fewer oil additives.



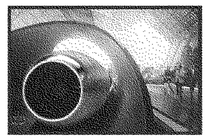
Put the jolt in the Volt
Chevy's Volt would not be able to cruise on battery power were it not for the advanced cathode technology that emerged from a National Lab. The same technology is sparking a revival of America's battery manufacturing industry.

Cemented a new material
National Lab scientists have developed a novel and versatile material that blends properties of ceramic and concrete to form a non-porous product that can do everything from seal oil wells to insulate walls with extra fire protection. It even sets in cold weather.

Pioneered efficient power lines
New kinds of power lines made from superconductors can carry electric current with no energy loss. Now deployed by National Lab scientists, these prototypes could usher in a new era of ultra-efficient power transmission.

Made early universe quark soup
National Lab scientists used a particle collider to recreate the primordial soup of subatomic building blocks that last existed shortly after the Big Bang. The research is expanding scientists' understanding of matter at extreme temperatures and densities.

Levitated trains with magnets



Say goodbye to traffic jams. National Lab scientists developed a technology that uses the attractive and repulsive forces of magnets to levitate and propel trains. Maglev trains now ferry commuters in Japan and China and will be operational in other countries soon.

Developed efficient burners
National Lab researchers developed cleaner-combusting oil burners, saving consumers more than $25 billion in fuel costs and keeping more than 160 megatons of carbon dioxide out of Earth's atmosphere.

Improved automotive steel
A company with National Lab roots is pioneering a metal that weighs significantly less than regular steel, retains steel's strength and malleability and can be fabricated without major modifications to the automotive manufacturing infrastructure.

Looked inside weapons
National Lab researchers created a device that could identify the contents of suspicious chemical and explosive munitions and containers, while minimizing risk to the people involved. The technology, which quickly identifies the chemical makeup of weapons, has been used to verify treaties around the world.

Pioneered nuclear safety modeling
National Lab scientists began developing the Reactor Excursion and Leak Analysis Program

(RELAP) to model nuclear reactor coolant and core behavior. Today, RELAP is used throughout the world and has been licensed for both nuclear and non-nuclear applications, including modeling of jet aircraft engines and fossil-fuel power plant components.

Identified good and bad cholesterol

The battle against heart disease received a boost in the 1960s when National Lab research unveiled the good and bad sides of cholesterol. Today, diagnostic tests that detect both types of cholesterol save lives.

Unmasked a dinosaur killer

Natural history's greatest whodunit was solved in 1980 when a team of National Lab scientists pinned the dinosaurs' abrupt extinction on an asteroid collision with Earth. Case closed.

Pitted cool roofs against carbon dioxide

National Lab researchers and policy experts led the way in analyzing and implementing cool roofing materials, which reflect sunlight, lower surface temperature and slash cooling costs.

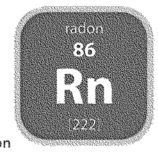
Squeezed fuel from microbes

In a milestone that brings advanced biofuels one step closer to America's gas tanks, National Lab scientists helped develop a microbe that can produce fuel directly from biomass.

Tamed hydrogen with nanoparticles

To replace gasoline, hydrogen must be safely stored and easy to use, which has proven elusive. National Lab researchers have now designed a new pliable material using nanoparticles that can rapidly absorb and release hydrogen without ill effects, a major step in making fuel-cell powered cars a commercial reality.

Exposed the risk



You can sleep easier thanks to National Lab research that quantified the health risk posed by radon gas in parts of the country. Subsequent EPA standards, coupled with radon detection and mitigation measures pioneered by a National Lab research team, prevent the naturally occurring gas from seeping into basements, saving thousands of lives every year.

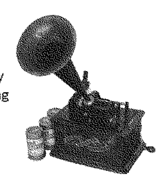
Created a pocket-sized DNA sampler

A tool that identifies the microbes in air, water and soil samples is fast becoming a workhorse in public health, medical and environmental cleanup projects. Developed by National Lab scientists, the credit-card-sized device pinpoints diseases that kill coral reefs and catalogs airborne bacteria over U.S. cities. It also was used to quickly categorize the oil-eating bacteria in the plumes of the Deepwater Horizon spill.

Fabricated the smallest machines

The world's smallest synthetic motors — as well as radios, scales and switches that are 100,000 times finer than a human hair — were engineered at a National Lab. These and other forays into nanotechnology could lead to life-saving pharmaceuticals and more powerful computers.

Preserved the sounds of yesteryear



National Lab scientists engineered a high-tech way to digitally reconstruct aging sound recordings that are too fragile to play, such as Edison wax cylinders from the late 1800s. Archivists estimate that many of the millions of recordings in the world's sound archives, including the U.S. Library of Congress, could benefit from the technology.

Exposed explosives

A credit-card sized detector developed by National Lab scientists can screen for more than 30 kinds of explosives in just minutes. The detector, called ELITE, requires no power and is widely used by the military, law enforcement and security personnel.

Toughened airplanes

A National Lab and industry technique for strengthening metal by bombarding it with laser pulses has saved the aircraft industry hundreds of millions of dollars in engine and aircraft maintenance expenses.

Simulated reality

Trains, planes and automobiles — and thousands of other objects — are safer, stronger and better-designed thanks to computer simulation software, DYNA 3D, developed by National Lab researchers.

Detected the neutrino

Starting with the Nobel-Prize winning discovery of the neutrino in 1956 by Fred Reines and Clyde Cowan Jr., National Lab researchers have made numerous contributions to neutrino physics and astrophysics.

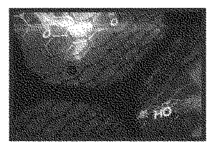
Discovered gamma ray bursts

Sensors developed at the National Labs and placed aboard Vela satellites were used in the discovery of gamma-ray bursts (GRBs) in 1973. GRBs are extremely energetic explosions from distant galaxies. Scientists believe that most of these bursts consist of a narrow beam of intense radiation released when a rapidly rotating, high-mass star collapses to form a neutron star, a quark star or a black hole.

Created the first 100-Tesla magnetic field

National Lab scientists achieved a 100.75-Tesla magnetic pulse in March 2012, setting a world record. The pulse was nearly 2 million times more powerful than Earth's magnetic field. The 100-Tesla multi-shot magnet can be used over and over again without being destroyed by the force of the field it creates, and produces the most powerful non-destructive magnetic field in the world.

Froze smoke for hot uses



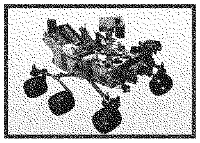
National Labs researchers perfected aerogels, known as frozen smoke. They are one of the lightest solids ever made and have the highest heat resistance of any material tested. They also are fireproof and extraordinarily strong — able to support more than a thousand times their own weight. As a result of their heat resistance, aerogels are outstanding candidates for insulation in buildings, vehicles, filters and appliances.

Invented the cell sorter

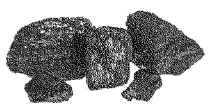
During the 1960s, a National Lab physicist invented a "cell sorter" — a novel device that works much like an ink jet printer, guiding a tiny flow of cell-containing droplets so cells of interest can be deflected for counting and study. Cell sorters are a vital tool for studying the biochemistry behind many diseases, including cancer and AIDS.

Ushered a domestic energy renaissance

National Lab research jump-started the shale gas revolution by pointing the way to key technologies and methodologies for cost efficient extraction. An estimated $220 million in research and development expenditures on unconventional gas R&D from 1976 to 1992 have resulted in an estimated $100 billion in annual economic activity from shale gas production alone.



Enabled space exploration
National Labs invented Laser-Induced Breakdown Spectroscopy (LIBS), the backbone of the device that allowed the Curiosity Rover to analyze material from Mars. Lab researchers also found the right combination of materials to make high-efficiency solar cells for spacecraft.



Sharply curtailed power plant air emissions
National Lab scientists introduced some 20 innovative technologies — such as low nitrogen oxide (NOx) burners, flue gas desulfurization (scrubbers) and fluidized bed combustion — through the Clean Coal Technology Development Program that have deeply penetrated the marketplace, substantially controlled harmful power plant emissions and benefited energy production and air quality.

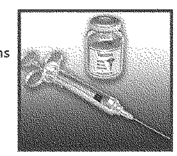
Made wind power mainstream
Increasing wind turbine efficiency with high efficiency airfoils has reduced the cost of wind power by more than 80 percent over the last 30 years. Now deployed in wind farms nationwide, these turbines owe their existence to National Lab research.

Engineered smart windows
National Lab scientists have created highly insulated windows that change color to modulate interior temperatures and lighting. If broadly installed, they could save about 5 percent of the nation's total energy budget.

Delivered troops safely
National Lab researchers have developed computer models that effectively manage the complex logistical tasks of deploying troops and equipment to distant destinations.

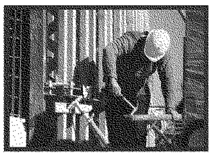
Channeled chips and hips
Integrated circuits and artificial hips owe their success to a National Lab discovery that revealed how to change a material by injecting it with charged atoms, called ions. Ion channeling is now standard practice in industry and science.

Made 3D printing bigger and better
A large-scale additive manufacturing platform developed by a National Lab and an industry partner printed 3D components 10 times larger and 200 times faster than previous processes. So far, the system has produced a 3D-printed sports car, SUV, house, excavator and aviation components.



Purified vaccines
National Lab researchers adapted nuclear separations technology to develop a zonal centrifuge used to purify vaccines, which reduces or eliminates unwanted side effects. Commercial centrifuges based on the invention produce vaccines for millions of people.

Built a better building
A National Lab has built one of the world's most energy efficient office buildings. The facility, operating as a living laboratory at a lab site, uses 50



percent less energy than required by commercial codes and only consumes energy produced by renewable power on or near the building.

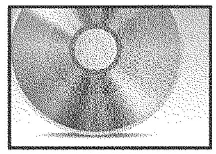
Improved airport security
Weapons, explosives, plastic devices and other concealed tools of terrorists are easier to detect thanks to technology developed at a National Lab and now installed in airports worldwide.

Improved grid resiliency
A National Lab created an advanced battery that can store large amounts of energy from intermittent renewable sources — such as wind and solar — onto the power grid, while also smoothing over temporary disruptions to the grid. Several companies have licensed the technology and offer it as a commercial product.

Solved a diesel dilemma
A National Lab insight into how catalysts behave paved the way for a new, "lean-burn" diesel engine that met emissions standards and improved fuel efficiency by 25 percent over conventional engines.

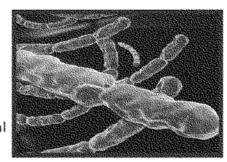
Harvested energy from air
A miniature device — commercialized by private industry after a National Lab breakthrough — generates enough power from small temperature changes to power wireless sensors or radio frequency transmitters at remote sites, such as dams, bridges and pipelines.

Gone grid friendly
Regulating the energy use of household appliances — especially at peak times — could slash energy demand and avoid blackouts. A National Lab appliance-control device senses grid stress and responds instantly to turn off machines and reduce end-use demand, balancing the system so that the power stays on.

Put the digital in DVDs


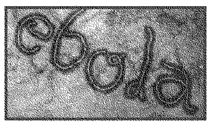
The optical digital recording technology behind music, video and data storage originated at a National Lab nearly 40 years ago.

Locked nuclear waste in glass
Disposal of U.S. Cold War waste is safer thanks to National Lab scientists who developed and deployed a process to lock it into glass to keep it from leaching into the environment.

Cleaned up anthrax


Scientists at a National Lab developed a non-toxic foam that neutralizes chemical and biological agents. This foam was used to clean up congressional office buildings and mail rooms exposed to anthrax in 2001.

Removed radiation from Fukushima seawater
After a tsunami damaged the Fukushima Daiichi nuclear power plant in 2011, massive amounts of seawater cooled the reactor. A molecular sieve engineered by National Lab scientists was used to extract radioactive cesium from tens of millions of gallons of seawater.



Sped up Ebola detection

In 2014, researchers from a National Lab modeled the Liberian blood sample transport system and made recommendations to diagnose patients quicker. This minimized the amount of time people were waiting together, reducing the spread of Ebola.

Prevented unauthorized use of a nuclear weapon

In 1960, National Lab scientists invented coded electromechanical locks for all U.S. nuclear weapons. The switch blocks the arming signal until it receives the proper presidential authorization code.

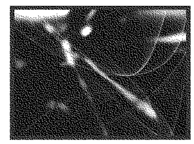
Launched the LED lighting revolution

In the 1990s, scientists at a National Lab saw the need for energy-efficient solid-state lighting and worked with industry to develop white LEDs. Today, white LEDs are about 30 percent efficient, with the potential to reach 70 percent to 80 percent efficiency. Fluorescent lighting is about 20 percent efficient and incandescent bulbs are 5 percent.

Mastered the art of artificial photosynthesis

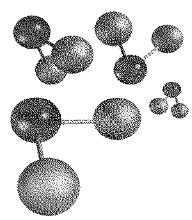
National Lab scientists engineered and synthesized multi-layer semiconductor structures in devices that directly convert sunlight to chemical energy in hydrogen by splitting water at efficiencies greater than 15 percent. This direct conversion of sunlight to fuels paves the way for use of solar energy in applications beyond the electrical grid.

Advanced fusion technology



From the first fusion test reactor to briefly produce power at the megawatt scale, and the world's largest and most energetic laser creating extreme conditions mimicking the Big Bang, the interiors of planets and stars and thermonuclear weapons, to the international experiment to generate industrial levels of fusion energy from burning plasmas, fusion science and applications are advancing because of the National Labs.

Made the first molecular movie



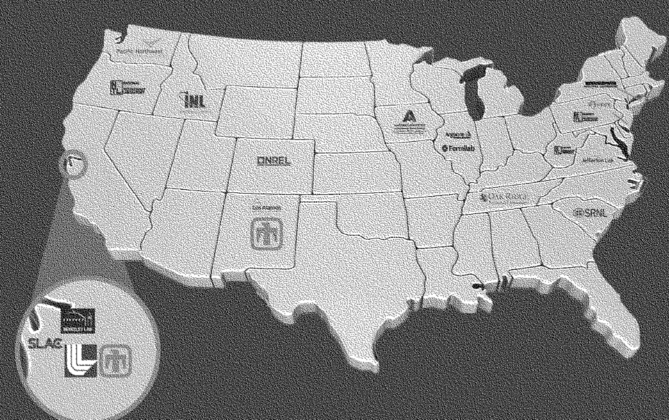
National Lab scientists have used ultrafast X-rays to capture the first molecular movies in quadrillionths-of-a-second frames. These movies detail the intricate structural dances of molecules as they undergo chemical reactions.

The National Laboratory System

Protecting America Through Science and Technology

U.S. DEPARTMENT OF ENERGY

For more than 75 years, the Department of Energy's national laboratories have solved important problems in science, energy and national security. This expertise keeps our nation at the forefront of science and technology in a rapidly changing world. Partnering with industry and academia, the laboratories also drive innovation to advance economic competitiveness and ensure our nation's future prosperity.



Ames Laboratory
Ames, Iowa

Argonne National Laboratory
Argonne, Illinois

Brookhaven National Laboratory
Upton, New York

Fermi National Accelerator Laboratory
Batavia, Illinois

Idaho National Laboratory
Arco, Idaho

Lawrence Berkeley National Laboratory
Berkeley, California

Lawrence Livermore National Laboratory
Livermore, California

Los Alamos National Laboratory
Los Alamos, New Mexico

National Energy Technology Laboratory
Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania

National Renewable Energy Laboratory
Golden, Colorado

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Pacific Northwest National Laboratory
Richland, Washington

Princeton Plasma Physics Laboratory
Princeton, New Jersey

Sandia National Laboratory
Albuquerque, New Mexico

Savannah National Laboratory
Aiken, South Carolina

SLAC National Accelerator Laboratory
Menlo Park, California

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

I just thought I would go through a few of these. It is pretty phenomenal.

Our labs fabricated the smallest machines. The world's smallest synthetic motor, as well as radios, scales and switches that are 100,000 times finer than a human hair were designed at our national labs. And it is important to talk about, okay, that is great, but how do you turn on a radio that is that small? Well, these are the forays into nanotechnology that could lead to life-saving pharmaceuticals and more powerful computers.

We are talking about a national lab discovery on freezing smoke and the smoke is actually fireproof which, there is an irony there, it is incredible to think about why would you freeze smoke and how did we come up with this, but what can it do? Well, it is heat-resistant aerogels that are candidates for insulation in buildings, vehicles, filters in appliances. These are things that are life-altering, life-changing, life-improving.

Ms. Ratnayake, in your comments and testimony you stated, "There's this role, an appropriate role, for industry. There is an appropriate role for the national lab system."

These discoveries and the partnerships you do together in industry, tell me the importance of federally funding and assuring appropriate and full robust funding for our national labs. What does that mean to Duke and to private industry?

Ms. RATNAYAKE. Certainly, Senator.

You gave some really good examples. They may not necessarily be anything specific, but the energy examples are equally transformational.

We work with a number of national labs to understand how to integrate the new technologies that are coming to us. So it's not necessarily fundamental sciences, but the fact of the matter is we can't operate on a system with technology solutions that doesn't have history.

That's where the national labs have helped us, particularly NREL has helped us immensely. The capability NREL has within its campus allowed us to test different components before any of it went on our system—we had to operate in real time and our customers would be impacted.

Most of the studies we've done with them has helped us to understand—when I have a large amount of solar, for example, on a single circuit, how do I operate it without the end customer being impacted because of the variability you see in its production?

We've had multiple opportunities to work with NREL to visualize what that future looks like which, within our facilities, we can't. We don't have those tools. As I mentioned, we don't have the resources or the incentives as an industry to look at that.

So our back-up position is to say, you're an unproven technology, I can't adopt you. In the absence of a lab, that's all in the absence of a lab, then public-private partnerships, that's really my back-up position or I have to wait until somebody else puts a solution on our system and hope that I know what I'm doing when I have to operate it. This gives us that, sort of, fail-proof approach process to experience things before they become reality on my system.

Hopefully I'm answering your question.

Senator GARDNER. Thank you.

Then there are some who might say that our national labs or the research labs in the Federal Government are infringing or duplicating the work that is being done by the private sector. But that is simply not true because of what you just answered and explained, that you would not be doing what you do without that.

Ms. RATNAYAKE. Right.

So you can think of us in, sort of, with two different roles. We, as the utility industry, are really the end user of a number of technologies that get developed by various entities. Some of them, I would say a very large number of the ultimately commercialized technology, would have started in a place like a national lab or in a place like an ARPA-E funded program. By the time it comes to us, the remaining research and development is all about how do I take a scientifically proven component and make it a part of this grid that we have to operate with 100 percent reliability every single day if we possibly can. I can't take the risk of putting that component without knowing how it would interact with 12 other parts.

None of the equipment manufacturers who deliver individual components have that interest. That's the unique place that national labs help us to bridge the gap. If they did not have the ability, if each individual component wasn't able to go and become a part of these testing facilities and proving, it's just not going to be commercially viable.

So anybody who says the national labs are infringing upon the potential of the private sector perhaps doesn't understand the complexity of the system we are operating.

Senator GARDNER. Thanks, Ms. Ratnayake.

Dr. Tumas, you are off the hook for this round. I am going to come back to you though next time.

We will go to Senator Heinrich.

Senator HEINRICH. Well, I want to start by thanking the Chair for holding today's hearing and the witnesses have already presented an incredibly strong case for how valuable the Department of Energy's 17 national laboratories are to our energy future and to our nation's economy.

In New Mexico, we are proud to be home to two of DOE's largest national laboratories, Los Alamos and Sandia. Both labs play critical roles in both national security and development of advanced energy technologies.

For a number of years now I have worked here in Congress and with our two national labs in New Mexico to improve the process to transfer those innovative technologies from the labs into the private sector. Technology transfer and partnering with the private sector is a critical part of a laboratory's mission and key to increasing the economic impact of federal research dollars.

Our national labs produce a steady stream of advanced technologies that we have heard about a little bit today that can yield big dividends in commercial markets. To improve the rate of transition of laboratory-developed energy technologies into commercial development, I believe we need to strengthen DOE's programs to promote stronger, direct partnerships with that private sector.

To do that, today I am proud to say I am introducing a bill with Senator Gardner, the Energy Technology Maturation Act, which authorizes a program at DOE to provide dedicated funding to help bridge the gap between lab research and development and a commercial product the private sector can produce and market.

I am also pleased to say that, in addition to Senator Gardner and I, Senators Bennett, Durbin, Manchin and Harris are original cosponsors on that bipartisan bill and we are looking forward to hearing from Senator Franken, why he is not on that list.

[Laughter.]

Tech transfer is a major job creation opportunity that we cannot afford to miss, even in Minnesota——

Senator GARDNER. He is still——

Senator HEINRICH. ——and our bill will create an environment that strengthens our economy while encouraging future innovations.

[Laughter.]

Senator FRANKEN. I have never been blindsided like this.

Senator HEINRICH. So I want to thank all of you for joining us today, and I am going to yield for a moment because I think my colleague from Minnesota is a little upset with me.

Senator FRANKEN. I have never been blindsided like that, Senator, and I resent it. I am joking, I don't.

Senator HEINRICH. Okay.

Senator FRANKEN. It looks good. I will look at the bill. If you guys are doing it, it sounds good.

Senator HEINRICH. Great.

[Laughter.]

Back to our witnesses.

I want to thank our lab witnesses and just ask your thoughts, from the perspective of the labs. What is working in the world of tech transfer? What are you seeing that is enabling that to happen more effectively? And what isn't? And what can we do about it?

Do any of you want to share your thoughts on that? We will start with Dr. Kearns.

Dr. KEARNS. Yes, let me jump right in because this is an area, as I said, I'm pretty passionate about and excited to be able to answer the question or at least start the discussion.

I think there are two things that I would cite as working well. And one is really thinking beyond the transactional relationships with industry to, really, more strategic relationships with industry.

No offense to our panelists here, but we have recently struck a long-term agreement to provide science and technology and strategic planning support for Exelon, one of the larger utilities in the U.S. So we're pretty excited about that. It's fairly open and it's a cooperative research and development agreement which allows us to have a great deal of flexibility and really allows us to pursue many different avenues of potential interest that Exelon may have in thinking about their own research and development activities.

As has been commented on, they've turned—utilities today in a regulatory, regulated environment, have great difficulty in conducting research and development activities. So they've turned to not only Argonne National Laboratory, but they've turned to MIT and Northwestern with similar kinds of arrangements, really, to pull the laboratories and those universities in to their thinking in terms of what the future might look like, how they might best position themselves for the future and what new technologies they should explore. So that's one.

A second is a new activity at Argonne we call chain reaction innovations which is sponsored by the DOE's Office of Advanced Manufacturing. It kind of turns things around in terms of how we do tech transfer and that actually invites innovators and entrepreneurs, they turn out to be fairly young for the most part, to the laboratory to actually use our facilities and to work with our researchers, side by side.

It's done through a competitive process and we are just launching the second cohort, if you will, where we can actually have young, fresh minds just out of college, or perhaps they've just finished their postdocs, really present their ideas. They're selected through a competitive process. As I said, we team them with researchers at the laboratory, as well as a business mentor to really help create a winning environment for them so they can really be successful in terms of what they do. And it really spans the field of interest, the ones we have, all the way from basic fundamental science to new ideas in chemistry, to all the way to looking at advances in nuclear energy technologies. So it's really been well received in those regards.

So those are two things that I would cite as that are working very well.

Senator GARDNER. Since we gobbled up a little bit of your time, Senator Heinrich, if you would like to ask a little bit more, you can.

Senator HEINRICH. Actually, I would, if either of our other witnesses from either NREL or West Virginia want to chime in, I am more than——

Dr. TUMAS. Yes, thank you, Senator.

At NREL we think we need to be as innovative in reaching out to partners as we are in our research. And clearly, I think that true partnership is important. I like to tell my international colleagues in some of our collaborations that collaboration is much like American football. It's a contact sport.

And access to the labs for small companies—there are many innovative mechanisms that have been developed over the years for that.

I joined Los Alamos about the time in 1993 that craters started to become very important. I spent 17 years there. One of our energy frontier research centers is led by Los Alamos, but NREL is an active participant. And you may know that some of the quantum dot technologies developed there are actually in spin-off companies in Los Alamos County today.

Senator HEINRICH. Right, absolutely.

Dr. TUMAS. It's very clear that innovative mechanisms are important.

We've developed some partnerships. One is with the Wells Fargo Foundation where we have 20 startup companies that have access to national lab capabilities for testing, proof of concept, and de-risking. Wells Fargo has just elected, the foundation has just elected to go select another 30 companies to participate there. Very different mechanisms.

We have energy material networks that were just set up that I talked about. One is DuraMAT. It focuses on materials for photovoltaic modules. It's led by NREL, but it has three other labs: Sandia, the Stanford Linear Accelerator and Lawrence Berkley lab. Each has a role in big data, materials reliability, materials modeling, but there's an industry board of active photovoltaic companies as well as along the supply chain with companies that sit on that board, help guide the research, but it's a mechanism to actually provide ready, as needed, access to laboratory capabilities. And so, they're there when they're needed.

Senator HEINRICH. Great.

Senator GARDNER. Thank you, Senator.

I am grateful to be a co-sponsor of the legislation which links the two together, meaning the kind of value stream that we need when it comes to those investments, getting them commercialized. So I appreciate your leadership in this area, Senator Heinrich.

Senator Franken.

Senator FRANKEN. Thank you.

It is like football, you were saying? What were your degrees from what schools?

Dr. TUMAS. I had the pleasure of watching John Elway for three years at Stanford, Sir.

Senator FRANKEN. No, no, no.

[Laughter.]

Oh, you were at Stanford?

Senator GARDNER. Great answer, thank you.

Senator FRANKEN. Okay, but I thought I heard Caltech and MIT, whose football programs rival Yeshiva's.

[Laughter.]

I am concerned about the budget cuts that President Trump is making in research, funding for research and development across the government which, I think, puts at risk our international competitiveness and innovative edge, not to mention jobs, is especially pronounced at the Department of Energy.

The budget slashes energy science and research programs by $3.1 billion, including cutting renewable energy and energy efficiency research by 70 percent, and it completely ends ARPA-E.

These cuts would have serious impacts on our national labs which, truly, are the envy of the world. The Administration justifies these cuts by expecting the private sector to pick up the slack, stating that the budget, "reflects an increased reliance on the private sector to fund later stage research, development and commercialization of energy technologies."

It seems like the Administration is buying into, kind of, the Heritage Foundation fantasy that ignores the long-standing research model that has been so effective in the United States and are now subscribing to, really, a dangerous approach and, I think, a naive one, that innovative technologies do not need assistance to transition from the lab and that there is no federal role through public-private partnerships and other types of support. They are rejecting the model that played a critical role in the development of the internet, for just one example.

Also, Mr. Tumas, you talked about getting oil and gas from shale, that kind of partnership.

Ms. Ratnayake, you work in the private sector. Is Duke Energy planning on substantially increasing its investment in energy research and development in lieu of those proposed DOE cuts? Are any industry consortiums contemplating the next Bell Labs, say, for energy innovation?

Ms. RATNAYAKE. We are not, Senator Franken.

Senator FRANKEN. And I would like to hear from the rest of the panel.

If these cuts go through, how will that impact the lab's ability to create and retain top talent?

Dr. ANDERSON. I know from a university perspective it would have a dramatic effect on the next generation of innovators, the next generation of scientists, who are funded through the Department of Energy programs at our universities and through our national laboratories.

And while I have the mic, Senator Franken, as you alluded to earlier, in terms of our national competitiveness, I can speak frankly with our U.S./China Clean Energy Research Center Advanced Coal Technology Consortium, that through that partnership, through that bilateral partnership, we get to see firsthand the innovation engine that exists in China. And so, cuts to our scientific endeavors in the United States, both at the basic level as well as applied and tech transfer, there is a vast economy that is ready to take our place.

Senator FRANKEN. So if we pass the President's budget, we are ceding our leadership to China and to other countries, in your opinion?

Dr. ANDERSON. It makes it very difficult for us to maintain our foothold, yes.

Senator FRANKEN. That is what I believe.

I am going to turn to energy storage because, Ms. Ratnayake, you were talking about solar energy and the problem you have with it being intermittent and how to deal with that.

I believe that energy storage is a key to facilitate widespread deployment of renewable energy. It can also be used to improve grid reliability and resilience or to avoid more expensive upgrades. Do you agree with that?

Ms. RATNAYAKE. Yes, Senator Franken. Energy storage has multiple characteristics that could help across our entire value chain. And I would perhaps say all the components you recognize, that there are many different ways to solve them. Energy storage definitely has a role to play there.

Senator FRANKEN. Thank you.

May I just continue on this path here?

Mr. Kearns, can you talk about some of the recent advances in energy storage that are coming out of Argonne National Lab as part of the Joint Center for Energy Storage Research?

Dr. KEARNS. Yes.

We have a very active program in energy storage research. Working with today's technology, as well as what we call beyond lithium ion, there's been a real significant investment by the Department of Energy, certainly with support of Congress, in the Joint Center for Energy Storage Research over the last four years.

Great progress has been made in looking at transportation, energy storage technologies through transportation applications, but also grid storage applications which has been the focus.

New materials, a great deal of fundamental, scientific research has been done as well to help us understand those materials and how they would perform, if you will, in terms of deployment at a battery cell whether it be for a vehicle or in the electric grid.

So, very good news, really, lots of promising development. We're not done. We have work yet to do. We have some fundamental science questions that need to be answered before we can actually move to, really, deployment of those technologies to industry. But great, significant work has been accomplished.

Senator FRANKEN. What can this Committee do to support you as you develop more reliable, efficient, and cost-effective advanced energy storage?

Dr. KEARNS. Certainly, continued investment, continued funding is really essential. I think support of active partnerships, which we've talked about a great deal today. The Joint Center for Energy Storage Research includes five national laboratories and four prominent universities, as well as four industrial partners. And so, that collaboration across the full spectrum of interest and capabilities is really needed.

Industry participation involvement has really helped us keep the eye on the target, if you will, and really understand some of the challenges that they foresee in terms of actually manufacturing materials and moving those materials into the marketplace. So that full spectrum of partnership support is really needed as well in engagement.

Senator FRANKEN. Yes.

Thank you for letting me run over. Thank you to all of our witnesses. You are all terrific.

I just want to emphasize that I really think that we disinvest in this research at our peril and that the Administration has budgeted Draconian cuts, as far as I am concerned, to our labs and to the advanced research that we do there and that we would be ceding leadership to China and probably other countries as well, that if anything, at this time when we know that we are in a period of, we are seeing the results of climate change around the world and we know that it is happening. And whether you believe it is manmade or not, which 97 percent of peer-reviewed scientists believe it is changing and there is something we can do about it, and just from the standpoint of it is cheaper to do wind.

You know that in Colorado, my goodness.

Senator GARDNER. And in Congress.

[Laughter.]

Senator FRANKEN. Yes.

It is cheaper to do solar and—China is choking on its fumes, and we want the business. I want the business coming from New Mexico and Colorado and from Minnesota.

If we don't invest in our labs, in our research, it is really so counterproductive for our country's future. I just cannot emphasize that enough.

I want to thank you all, again, for your work and your testimony.

Senator GARDNER. Thank you, Senator Franken.

We will go another round if you would like. Is that alright with you, to go a little bit more?

Senator HEINRICH. Yes. Absolutely.

Senator GARDNER. Dr. Tumas, Senator Franken mentioned battery storage. Did you want to talk a little bit about some of the storage work you are doing at NREL as well?

Dr. TUMAS. Sure. Sure, I would.

I think there's really—Dr. Kearns did a great job and Argonne's been actively engaged for a long time.

I think what we're going to see in energy storage is we're going to have to couple energy storage with energy generation. We're going to see systems integration be important.

I like to think of our work at NREL and among the national labs as, kind of, systems-driven and analysis-based research. We both have to look at what are the fundamental limitations of current technologies but we have to develop the future, next generation concepts as well. And we know some of those limits.

The other thing that I think is really important is, as a chemist I'm fascinated by, not only what we can do by putting electrons into electrodes, but what can we do by putting electrons into chemical bonds?

And so, we know how to electrolyze water to make hydrogen and oxygen and we know how to take hydrogen and oxygen back to electricity. We know some of the limits of those, but we know that those can help very much with grid integration at large scale.

As we think about energy on very different—what we do for the car might be very different than what we do for the grid, long-term. So thinking about how to interconvert electrical and chemical energy is a grand challenge that all the labs and a number of universities need to address, how to make those efficient.

The other one—it's really important and we've done this in solar for a long time and now, I think, we're going to have to do it in PV battery systems. And that's the, not just understanding, but actually predicting lifetimes, predicting reliability, predicting durability. All the kind of de-risking that our colleague from Duke Energy talked about to really make technologies viable.

And we can't just try to predict 30 years by studying something, testing it for 30 years and then moving forward. We have to understand degradation mechanisms. There's fundamental science there, but there's plenty of applied science as well.

Senator GARDNER. Yes, thank you.

I am sorry, go ahead. I didn't mean to interrupt, I am sorry, did I interrupt you?

Dr. TUMAS. No, that's fine, sir.

Senator GARDNER. Thank you.

Dr. Tumas, just looking at your background, you went through industry, research and development. You went through two national laboratories and we have talked about other nations that are copying the successes that we have had in our national laboratory system, other nations that are ramping up significantly their investments, the concern I have with the reduced funding for our national lab system.

But I also worry about the fact that, you know, if there is this uncertainty in our national lab system, does it continue to draw the brightest minds? Does it continue to be the magnet for the best and the brightest in innovation and research and science?

So tell me a little bit about mission-driven science, the system of engineering that DOE has that brought you and kept you in the national lab system and what it is about that system that draws people from within the 50 states, but also from around the world to these magnets of innovation?

Dr. TUMAS. So I think it's a couple of things. As I talked a little bit in my testimony, big challenges that require big solutions.

I think that one of the cultures you see at national laboratories, and you see it much more so even at some of the research institutions across the world, is the idea of teaming. I love storming, informing new teams to go after new challenges. It's really exciting to get a set of awesome scientists who have never worked together, working together from different disciplines on a very complicated problem.

We have a lot of postdocs and graduate students in my Energy Frontier Research Center. Almost all of them have spent some time at the Stanford Linear Accelerator where we can actually look at the synthesis of molecules in real time. And so, there's the kind of training and access to these facilities.

We now live in a world—I grew up in a world that was very discipline-focused. We now live in a world where graduate students and postdocs work very multidisciplinary. They spend time talking with theorists. They spend time doing advanced experimental work. We have many students and postdocs who are interested in policy and some of the analytical ramifications and scenarios of their research. So I think this ability for the lab system to really bring this multidimensional, multidisciplinary approach, in addition to specialized tools that can't be found anywhere else in the world, is really a critical magnet.

Senator GARDNER. Thank you.

Senator Heinrich.

Senator HEINRICH. Storage has been touched on quite a few times, and I think I might want to return to that a little bit with Dr. Kearns and Dr. Tumas.

But I wanted to mention, it is worth noting today that the DOE—and some of us following open source data have suspected this for a number of months—but the DOE has now said that we have officially hit our SunShot goals of $1.00 per watt. And we not only hit that goal, but we hit it three years early, Dr. Tumas. And back in 2011 when that was set, I think the equivalent is about $.06 unsubsidized per kilowatt-hour. Is that right, more or less? I think we were at $.27 per kilowatt-hour in 2011 for solar, to give you a sense of how steeply we are coming down that curve.

If you were to look out a few years, what in photovoltaics, in terms of new designs or new panel technologies, do you see that gets you excited, whether it is from the perspective of declining costs or increases in efficiency or even just integrated systems? What are you excited about that you see out there in the future that has not made it into the news just yet?

Dr. TUMAS. Great. Most of it is probably in the news somewhere but maybe it's not well-known, but I'd be glad to address that. Thank you for the question.

First of all, we, if you look at—so we're all delighted that the SunShot goal has been met and it's always great to meet your goals ahead of time. What's interesting is we're meeting it at a time where that slope of cost reduction is not yet flattening out. It's very clear, and there are road maps in EERE—the people that run the SunShot program have a road map for how to get to $.03 a kilowatt-hour. They suggest by 2030. I would suggest that that could be accelerated, potentially.

There also are major issues, as we talked about, with storage and intermittency on how to deal with a more reliable grid, how a two-way grid allows us to get even more solar onto the grid and wind and other things.

But from a material scientist standpoint, from a fundamental research, I think we're not done yet either. The four absorbers that are in commercial PV systems were actually known when I was in graduate school watching John Elway play football. And it turns out that only recently, there was a material 15 years ago that was worked on at IBM, and only about four or five years ago people in England and people in Switzerland took these materials, perovskites, and showed they could actually be a new solar material. In fact, NREL has an efficiency curve that plots the efficiency over time, and this has a slope that's been unprecedented.

And so, all of a sudden there's a whole set of new materials. At our own Energy Frontier Research Center we're trying to understand, as well as others, what is it about these materials that make them special? And while we're doing that we're also understanding that you can actually solution process these. We, and others, can actually do roll-to-roll printing of these materials and make 19 percent solar cells that could be printed like newspaper. And so, we start to see new form factors.

What's interesting about solar panels despite all the cost reduction and all the efficiency increases is they, kind of, still look like they did 35 years ago.

Senator HEINRICH. Very much.

Dr. TUMAS. And you can imagine building integrated photovoltaics, photovoltaics everywhere else, that might bring you power for different applications.

Clearly we, and a number of others, are working with the Department of Defense on how to take very high-efficiency solar, put it into flexible form factors.

So, there's many—much we can do, not just on materials discovery, but it turns out for solar cells, it's not just the material that matters, but it's how the materials interact. There's several layers in a solar cell. It's how those materials interact over time. It's how those materials are manufactured at a large scale and what that position looks like held up to a small scale. It really covers this whole spectrum from discovery, but then really marching it all the way through to a reliable, predictable, potentially new product.

Senator HEINRICH. Dr. Kearns, same question, but storage in terms of either additional chemistries——

Dr. KEARNS. Sure.

Senator HEINRICH. ——about thermal storage which we have not touched on, non-lithium ion applications, flow batteries, et cetera. What has you excited about the future?

Dr. KEARNS. Oh, a number of things, really, have us excited about the future of energy storage and thinking beyond lithium ion.

There's a great deal of interest in multivalent batteries which is, you know, part of the challenge associated with any battery is its capacity to store energy. By going from lithium ion to multivalent ion of some sort, you really increase the ability to store a great deal more energy. And so, we're very excited about that potential.

It's a great deal of literature that's been really created, scientific literature, to really, kind of, validate the thought and the idea and really begin to move toward some applications in that space.

I think also, certainly, new materials. If we look at electrolytes and cathodes and certainly a high interest in all kinds of different materials and new applications. Thoughts about membranes as well in this space that could really drive, if you will, greater efficiencies.

Big challenge, really, for energy storage, not only in terms of storage capacity, but also reducing the cost. And you see that real time, if you will, in terms of today's lithium ion technology.

We'd like to leapfrog, if you will, in terms of thinking about the next generation battery in terms of beyond lithium ion. There's something that is cost competitive to start in terms of where we're at today with lithium ion technology and drive it and improve it from there. So, a lot of excitement in terms of great promise, great potential there.

Flow batteries, you mentioned, certainly of high interest in terms of grid storage.

Senator HEINRICH. Great. Thank you very much.

Senator GARDNER. Thank you.

Well I can certainly tell from the panel the great pride that you approach your work with. Of course, the benefit to the country has been phenomenal over the past many decades, the work that you have all done in research innovation and development beginning with an idea of how we were going to win a war to today's ability to grow jobs, economy and remain the world's superpower of innovation.

I want to thank you for being here today, and thank all the panelists for your time and testimony today.

For the information of members, the record of this Committee hearing will remain open until Friday for questions for the record.

This is your homework assignment. I would ask that you respond to those questions as quickly as possible.

With the thanks of this Committee, the Committee is now adjourned.

[Whereupon, at 4:19 p.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

United States Senate Committee on Energy and Natural Resources
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Fostering Innovation: Contributions of the Department of Energy's National Laboratories
Questions for the Record Submitted to Dr. Bill Tumas

Questions from Senator Bernard Sanders

Question 1: *According to the Solar Energy Industries Association, the blended average solar PV price has fallen by more than $5/watt since 2009, and solar PV capacity has increased dramatically over the same period. Can you describe the role that research supported by the National Labs in general, and the Photovoltaic Regional Test Centers in particular, has played in bringing down the cost of solar PV?*

The price of solar PV has dropped to the point where it is competitive with conventional sources of electricity in some markets. The Department of Energy's SunShot program recently announced its 2020 utility-scale goal of $1 per watt, or 6 cents a kilowatt hour, has been achieved three years early. This reduction in price is a result of a number of concurrent factors around the globe, including the research conducted by National Labs and the PV Regional Test Centers (RTCs).

An example of National Lab contributions is the ongoing work by NREL and the largest U.S. solar module manufacturer, First Solar. The company adopted technology based on cadmium telluride born in NREL labs, and in the last decade has been the industry leader in steady cost reduction. Over the years NREL has collaborated with First Solar with a wide range of foundational research in PV materials, devices, and systems to better understand how to improve both performance and reliability. First Solar has stated publicly that they would not be where they are today without their collaboration with NREL. This work includes recent fundamental studies on materials required to increase their efficiency (published in the journal *Nature Energy* last year), which translates directly to increased competitiveness and performance for the technology.

Another example of how the National Labs are helping bring down the cost of solar PV is through grid integration research. Working both independently and in collaboration with industry leaders—Solar City/Tesla, First Solar, Google, numerous utilities (HECO, Duke, SCE, PREPA, APS, SDG&E, et al.), Enphase, the Hawaii PUC, the Electric Reliability Council of Texas, the California Independent System Operator and many others—NREL and other labs have contributed to many advances in PV to grid integration that have already increased solar jobs in the US and lowered costs across the value chain. For example:

- Accelerating interconnection reviews through streamlined processes and advanced modeling
- Developing algorithms and techniques that allow solar PV to benefit the grid by providing reliability services historically provided by central thermal generators.
- Foundational research on advanced algorithms to optimally utilize storage, smart grid controls, and other emerging technologies to enhance techno-economic operations of the power system.

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A relevant example of an important project by the Photovoltaic RTCs is the testing of technology for use in Tesla's solar roofs product development effort in a trusted, neutral setting and across multiple solar regimes. Tesla says this work will revolutionize how we think about installing solar on buildings. In addition to partnering with major solar firms Tesla and First Solar, the RTCs also strive to support smaller companies, especially those with innovative, yet still unproven concepts. Not all of these can be expected to reach commercial success, but this work too has pushed the envelope toward lower cost and greater efficiency in PV modules.

Overall, the RTCs have enabled U.S. manufacturers to demonstrate a strong track record of performance and reliability. In one project, U.S. microchip manufacturer Maxim Integrated turned to the RTCs to prove the functionality of their smart PV module (with their embedded power electronics), which can increase system energy output by up to 20 percent, relative to similar modules without the embedded power electronics. Based on the reliability and performance data compiled by the RTCs, U.S. manufacturer TenKSolar was able to contract with NRG Energy and MGM Resorts to win a contract and complete installation of one of the nation's largest rooftop solar arrays.

<u>Question 2</u>: *How will solar energy innovation be affected if public sector research and development, particularly the National Laboratories and the Regional Test Centers, is significantly curtailed? Is the private sector capable and willing to conduct the R&D necessary to move forward aggressively on renewable energy deployment throughout the country?*

Around the world, advanced energy solutions are expanding at unprecedented rates. Other countries are making significant government investments across the R&D spectrum in solar and renewable energy technology development. Federal investment in solar PV R&D is essential if the U.S. is to retain technical leadership in this growing industry.

Despite remarkable advances in the cost, performance and deployment for solar energy, there is much room for innovation at many levels. The DOE Sunshot Initiative has a compelling 2030 Strategy and FY18-22 Multi-Year Program Plan. Solar energy research is underpinned by fundamental research funded by the DOE Office of Science on materials discovery, solar photochemistry, condensed matter physics, computational materials science, and materials chemistry, all which is critical to understanding current materials and developing next generation concepts. The Department of Defense funds research that leverages national laboratory capabilities to develop high performance photovoltaics to reduce risks and costs associated with remote fuel supply.

The national laboratories offer unique capabilities and expertise that private industry alone cannot match. Industry excels at R&D that incrementally improves their manufacturing processes, their products, and interconnection practices, but the private sector's need for near term return on investment precludes spending on the foundational science that is needed to produce new game-changing technologies. Federally funded collaborative R&D among national

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laboratories, universities and industry can continue to provide the needed innovation for solar energy to: 1) approach the fundamental limits of current technologies, 2) accelerate emerging technologies and 3) develop next generation concepts and technologies.

New concepts to materials processing could lead to lower cost, less capital-intensive manufacturing processes. For example, in the last few years have we seen the advent of a new class of PV materials—hybrid perovskites. These materials lead to high efficiency PV solar cells that could compete with current technologies on price. They could provide novel coatings that could greatly enhance the efficiency of current technologies and could also lead to novel US-led manufacturing involving printing of high-efficiency, low-cost solar cells.

The RTCs are also significant drivers of technical innovation in the US: they provide a platform for evaluating new, potentially game-changing, technologies, collecting data that--along with performance analysis by the national labs--is essential to 1) providing early feedback to manufacturers to help refine their products; 2) bolstering investor and customer confidence in emerging technologies; and 3) growing and strengthening the US solar industry by validating and showcasing innovation.

As a nation, we will not remain ahead of the potential grid challenges of high penetration PV without the forward-looking, potentially disruptive innovations provided by national labs and RTCs. Broader deployment of solar will require expanding R&D on innovative energy storage, power electronics, PV systems, PV reliability, advanced algorithms, and energy systems integration including assuring resiliency, security, and reliability of the electric grid. Novel technologies such as Maxim's embedded power electronics, grid services from advanced inverters, and SolarWorld's bifacial photovoltaics require custom evaluation procedures, which have been developed in part at the National Labs and deployed at the Regional Test Centers. In contrast, existing third-party testing labs generally can only offer more routine test procedures best suited for the most conventional PV and inverter technologies. Advanced inverter control technologies already provide a pathway forward to managing voltage and providing disturbance ride-through to maintain and enhance grid reliability. Looking ahead recent algorithmic advances, such as distributed controls, synthetic inertia and harmonic-oscillator-based controls, show promise to support reliable grid operations with extremely high-penetrations of inverter-based technologies and to enhance grid resilience to natural and human threats. The national laboratories are also a source of reputable and unbiased data and analysis.

Question 3*: While there are no DOE National Laboratories in my state of Vermont, or anywhere in New England for that matter, the Photovoltaic Regional Test Center (RTC) in Williston, Vermont provides critically important research and performance verification of innovative solar technologies and energy storage devices in a very cold and wet climate. If federal funding for the RTCs in Vermont and around the country is reduced or eliminated, who will provide impartial performance verification of solar technologies? Can you speak to the role these RTCs play in developing affordable and effective solar technology for all U.S. markets?*

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The Regional Test Centers fill a valuable role in the independent and credible validation of U.S manufacturers' products. That is especially true for the most novel and promising of technologies. The infrastructure and procedures already deployed at the Regional Test Centers, coupled with the capabilities of the managing National Labs, are ideally suited for performance validation of innovative PV equipment. The Vermont Regional Test Center in particular has established itself with commercial firms because of its location and climate, and its record of successful partnerships with local, Vermont-based firms including All-Earth Renewables, Renewable NRG, and Norwich Technologies. The Vermont RTC is also actively working with Vermont Technical College to develop a curriculum utilizing the RTC as a classroom, a curriculum that can be leveraged by other university partners at other RTCs.

The Vermont RTC, with its severe winters, offers fielded performance-validation of new technologies not only in a region that consistently sees cold temperatures and significant snowfall but in a region (the Northeast) that is seeing some of the nation's fastest growth in PV per capita. As a result, the Vermont RTC site is the most popular with industry partners (greatest number of partners, largest number of kilowatts, and greatest diversity of technologies). The companies represented at the Vermont RTC have no other source of objective, independent long-term performance data for this region, data that are needed to build customer confidence in new lower-cost technologies and expand market share.

Questions from Senator Catherine Cortez Masto

Question 1: *Through the Department's research into geothermal energy through the Geothermal Technologies Office (GTO) and investment into energy projects with the Loan Guarantee Program, Nevada has been able to create multiple job producing clean energy power plants. Geothermal energy is one of the growing industries in Nevada. In 2013, there were 29 geothermal power plants operating in nine of Nevada's seventeen counties. Furthermore, the Sandia National Laboratories in Fallon is one of the two finalists for the Department of Energy's FORGE Lab. Can you tell me how the GTO's work with the National Labs is creating an environment for geothermal energy to continue its growth?*

The Geothermal Technologies Office (GTO) works in partnership with DOE's National Labs, academia, and industry on research activities that will enable the development of innovative and cost-competitive technologies and tools to locate, access, and develop geothermal resources in the United States. The U.S. geothermal industry currently has about 4 gigawatts (GW) of installed nameplate capacity—and the Geothermal Technologies Office is working with national laboratories such as NREL and Sandia, as well as other key stakeholders, to develop approaches to increase the U.S. generating capacity to 100 GW of geothermal power.

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The federal geothermal program's research and development activities are primarily focused on four areas: enhanced geothermal systems (EGS), hydrothermal resources, low temperature and coproduced resources, and systems analysis. FORGE is one of the program's key research initiatives. It will create a dedicated site and experimental research platform where scientists and engineers from the National Labs will join with university and industry colleagues to develop, validate, and accelerate breakthroughs in EGS technologies, and thus significantly increase the generating capacity of geothermal power of the United States. FORGE is just one example of how the Geothermal Technology program works with multiple National Labs so geothermal energy can continue to grow in many states across America.

Question 2: *The interim report of the Secretary of Energy Advisory Board (SEAB) National Laboratory Task recommended that each DOE National Laboratory should adopt a "personnel pathway that permits a limited number of staff to take entrepreneurial leave for a designated period" and many such entrepreneurial leave policies have begun to be implemented. At this early stage process, have you seen any evidence that these policies have improved the success for technology transfer at the laboratories? If so, how could they be strengthened in the future?*

DOE has not implemented new policies in this area, but rather is encouraging labs to create their own entrepreneurial programs consistent with each lab's mission and research environment. Thirteen labs now have entrepreneurial programs in place or are in the process of implementing new programs. In addition, there are a number of examples of innovative programs across the national lab complex designed to advance technology transfer. DOE's Energy I-Corps program (funded by DOE's office of Energy Efficiency and Renewable Energy and administered by NREL) is having a positive effect. This program provides training and preparation for lab staff from across the complex who are interested in seeing their technologies commercialized. NREL created The Wells Fargo Incubation Innovator (IN^2) is a five-year, $10 million program funded by the Wells Fargo Foundation and co-administered by NREL. It is designed to facilitate early-stage technologies providing scalable solutions to reduce the energy impact of commercial buildings. Participating IN^2 start-up companies have access to NREL's world-class facilities and researchers, who will test, validate, and incubate the companies' technologies to help them meet critical validation milestones on their path to the commercial marketplace.

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Question for the Record Submitted to Ms. Anuja Ratnayake

Question from Sen. Catherine Cortez Masto

Question: In June 2015, the Secretary of Energy Advisory Board (SEAB) National Laboratory Task Force submitted comments to the secretary of energy on the effectiveness of the National Laboratories. These comments included a number of observations on the "effectiveness, morale, and management of these vital national technical centers," including a recommendation that DOE "embrace the technology transfer mission." In your experience, what barriers have you identified which inhibit the establishment of working public-private partnerships at the National Laboratories?

Response: Thank you for your question. As I had testified, Duke Energy maintains very strong relationships with a number of National Laboratories and benefits from their research leadership regularly. However, in any working relationship there is always space for improvement. Here are the top three areas we'd recommend improvement:

1. Identifying technological needs
2. Administrative and contracting processes
3. Commercializing developed technologies

1. Identifying technological needs

The Department of Energy establishes the research priorities of the National Labs. As demonstrated by our project engagement, frequently there is overlap with Duke Energy priorities. As an industry, we are interested in deploying advanced technologies; however, our industry does not adopt technologies individually. We integrate technologies to the utility system to enhance customer value from the whole system. To achieve this goal, it is important that DOE sets holistic goals and priorities for National Labs research that keep the impact to the customer and taxpayer in mind. It can appear that the National Labs are focused on researching a particular hypothesis or technology of interest, instead of addressing ultimate customer needs. Having a closer relationship with technology adopters, such as the utility industry, during the goal-setting period could overcome this weakness.

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Due to the long lead time of new technologies, extensive reporting, and effort required for large multiyear projects, the National Labs are clearly targeting anticipated future needs instead of near-term opportunities. As technology advancements occur more rapidly across all sectors, there should be a mechanism to ensure multiyear projects remain relevant. Having closer industry engagement and promoting a culture of agility could help improve the value of multiyear R&D projects.

To better ensure alignment, it would be helpful to have a structure that formally connects industry with the National Labs and facilitates communication. In this structure, industry can share key research priorities and the labs can communicate their expertise. This will assist in aligning relationships and representatives as well as ultimately facilitating technology transfer when the opportunity arises.

2. **Administrative and contracting processes**

There is an administrative burden when working with DOE-funded grants due to the extensive reporting requirements. The grant process generally has very long lead times, and the current process to contract with a National Lab is lengthy.

It is also cumbersome to engage National Labs in privately funded, geographically specific research due to federal contracting requirements, which results in both schedule and cost inflexibility. This can lead the industry to have to look to other parties to bridge the gap between National Lab research and actual technology adoption.

3. **Commercializing developed technologies**

At the National Labs, the technology transfer effort often seems to stop at the creation of white papers and technical reports. Tools and expertise are of limited supply to enable transfer of the excellent technology that has been developed. These valuable technology advancements discovered by the National Labs become freely available resources to industry, but because of limited National Lab technology transfer efforts, the industry is not aware of their availability and as a result the technology may not be widely leveraged. ARPA-E, on the other hand, has a well-supported 'Technology to Market' team that helps connect researchers to private industry and facilitate the commercialization process. A similar skill set focused on technology transfer efforts would further strengthen the value of National Lab innovations.

In our experience, we have found that targeted communication of project findings, lessons learned and innovations is limited to project participants, even though they are generally relevant to much of the

United States Senate Committee on Energy and Natural Resources

Subcommittee on Energy

September 12, 2017, Hearing

Fostering Innovation: Contributions of the Department of Energy's National Laboratories

Question for the Record Submitted to Ms. Anuja Ratnayake

sector. One relatively simple avenue to expand tech transfer capability is to proactively communicate project key learnings and findings across a broader swath of the energy industry.

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Questions from Senator Joe Manchin III

Questions: I am working with a bipartisan group of elected officials on the concept of developing an Appalachian Storage Hub for natural gas liquids. When you consider the tri-state area of West Virginia, Ohio and Pennsylvania, it is hard to avoid noticing the abundance of natural gas and natural gas liquids, expanding energy infrastructure and the naturally occurring geologic storage primed for storing these products. These factors would make our tri-state area even more attractive to additional manufacturing investment. According to the Mid-Atlantic Technology Research & Innovation Center, about 20% of the value in the Marcellus Shale alone is ethane, propane and butane. So, the Hub would attract manufacturers that need reliable affordable access to these products. With safety and the environment top of mind, I'd like to see a Storage Hub move forward and that's why I introduced a bill making a storage hub eligible for the loan program at DOE.

What, in your opinion, could the development of a natural gas storage hub in a state, such as West Virginia, have in the area?

Response: With over half of the North American plastics converter market within 500 miles of Appalachia, the need for redundant transport is minimized while maximizing the value creation from the American resource. According to the American Chemistry Council analysis on the number of permanent jobs created in the Appalachian petrochemicals hub that may result from the construction of a natural gas liquids storage and subsequent trading hub would be 101,000, including 26,000 chemical and plastics manufacturing jobs, 43,000 in supplier industries, and 32,000 payroll-induced jobs and communities where workers spend their wages.

Potential Economic Impacts of An Appalachian Chemical Industry (Permanent, By 2025)				
Capital Investment ($2016)	Direct Output ($2016)	Employment	Payroll ($2016)	Federal, State, and Local Tax Revenue
$32.4 billion in petrochemicals, resins and derivatives **$3.4 billion** in plastic products	**$23 billion** in chemicals + plastic resins **$5.4 billion** in plastics compounding + plastics products	**25,664** direct jobs (chemical and plastics products manufacturing) **43,042** indirect (supply chain) jobs **32,112** "payroll-induced" jobs in local communities where workers spend their wages	**$1.7 billion** direct **$3.0 billion** indirect (supply chain) **$1.5 billion** payroll-induced	**$1.7 billion** in federal tax revenue annually **$1.2 billion** in state and local tax revenue annually
TOTAL: ***$35.8 billion***	***TOTAL: $28.4 billion***	***TOTAL: 100,818 jobs***	***TOTAL: $6.2 billion***	***TOTAL: $2.9 billion***

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The Appalachian Basin provides ready access to commercial markets for downstream products and a competitive pricing advantage due to the abundance of valuable, yet currently underpriced, hydrocarbons. Ethane storage capacity is key to the development of a robust Natural Gas Liquids (NGL) trading hub that will, in turn, reduce the risk of and further incentivize investments in regional chemical manufacturing and related product development industries. The U.S. and Appalachia would benefit from infrastructure development to satisfy the feedstock and offtake requirements for world scale and distributed manufacturing elements.

The construction on an NGL storage and trading hub would greatly benefit the Appalachia Region; however, the benefit applies further to the whole US economy through the reduction in two-way transportation costs destroy the value of our domestic raw materials. There are two options to build out the infrastructure necessary to support the Appalachian Basin production of natural gas and NGLs. One option is to build sufficient pipeline offtake capacity to transport the NGLs to the East Coast, particularly Marcus Hook, PA, or to the Gulf Coast to the NGL market at Mont Belvieu. While the option to build offtake capacity may be the easiest option, it is not the option that results in the global optimum system for the U.S. economy.

Transportation costs for transporting ethane via pipe from the Appalachian Basin to Mont Belvieu are approximately \$0.16, while the cost for rail transportation of propane is \$0.30. The current Mont Belvieu prices for ethane and propane are \$0.21 and \$0.43, respectively, indicating the inherent discount to in-basin utilization of NGLs is substantial. This results in the conclusion that the global optimum for the U.S. economy and the lowest cost of consumer goods to the U.S. consumer will come from a significant petrochemical expansion in the Appalachian Basin. Expansion of the petrochemical industry in Appalachia will allow the USGC to shift production capacity toward the export markets. In the March 6, 2017 press release announcing ExxonMobil's \$20 billion expansion on the USGC they indicate the focus is on the export market in high-growth nations. The expansion in Appalachia will support the domestic market, while the USGC can focus more heavily on export – resulting in a positive shift in the balance of trade while simultaneously providing U.S. consumers with lower costs of end goods.

Question: Do you have any recommendations for policy makers to help guide the successful development of the Appalachian Storage Hub?

Response: Large, free market systems do not always find the global minimum solution and trend toward the near-term, lowest barrier solution. When infrastructure development is a result of the near-term, local optimum solution, the barrier for correction is too high to overcome. This scenario, coupled with today's low hydrocarbon price and therefore low capitalization of companies in this sector provide the perfect storm for the system finding its local, not global, optimum. Companies in this sector cannot afford major capital outlays on their books. This situation calls for public intervention; the global economic optimum is in the greater public good. With the increased exports that can be realized and the lower domestic consumer good costs, the

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payback to the public sector will be realized through greater productivity, economic expansion, tax and tariff receipts.

This national economic payback, coupled with the economic security of a diversified petrochemical manufacturing sector calls for policy makers to ensure that there are federal options available for infrastructure development funding, such as the Title XVII DOE Loan Guarantee program as well as a clear pathway for permitting and a clear regulatory environment. Additionally, to maximize the impact to the economy, assistance to the states for development of suitable sites for expansion and revitalization of the Appalachian petrochemical industry. There are many brownfield sites in the region, but often these are not large enough to house significant petrochemical manufacturing facilities.

Question from Senator Catherine Cortez Masto

Question: Universities could be natural partners for the laboratories in the pursuit of regional economic development and many laboratories may have existing partnerships with States and universities to create centers of economic activity. The economic opportunity these types of partnerships could have in the rural areas of Nevada could be profound. How would you recommend that centers of higher education such as universities align and/or partner with the national laboratories to help multiply these types of partnerships?

Response: The United States' National Laboratory system is unparalleled in the vast talent pool and physical scientific resources. The recent Congressional Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL) identified as one of its recommendations that the National Laboratories should play a bigger role in in their regional economies. However, in rural regions and states the universities, particularly Land Grant Institutions, have a much more grass roots connection to rural areas such as those in Nevada and West Virginia. At West Virginia University we take our Land Grant Mission very seriously as that it is core to our existence that we help elevate the people and the economy of our state. To do this we have to be proactive and comprehensive. Universities can serve as a front door both for coordinating interaction between the National Laboratories and faculty as well as the communities. I would charge the University community to own this role. The National Laboratories are large, complex, and highly effective organizations, but must have the assistance of the universities as partners in economic development. It is only natural to create these partnerships as these two large and effective types of organizations share common goals.

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