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THE LEADING ROLE OF THE DEPARTMENT OF ENERGY IN AMERICAN ENERGY INNOVATION AND HOW ITS RESEARCH, DEVELOPMENT, DEMONSTRATION, AND DEPLOYMENT PROGRAMS MAY BE ENHANCED TO FURTHER BOOST THE ECONOMIC COMPETITIVENESS OF THE UNITED STATES

HEARING

BEFORE THE

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THURSDAY, APRIL 15, 2021

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

The Committee met, pursuant to notice, at 10:00 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Joe Manchin III, Chairman of the Committee, presiding.

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

The CHAIRMAN. The Committee will come to order.

Over the past few weeks, there has been growing conversation around the role research and development (R&D) plays in global competitiveness. I think it goes without saying that this Committee welcomes that discussion. The Department of Energy (DOE) and national laboratories and even the science agencies at the Department of the Interior engage in scientific research and discovery on a daily basis using the world's finest equipment, programming and, most importantly, the best and brightest minds. In particular, DOE and the 17 national labs, as well as their countless partners in universities and the private sector, formed the premier energy research development and commercialization enterprise in the world. As Chairman, I am committed to identifying the programmatic needs of DOE and the labs, building on their strengths and clarifying their roles in the broader federal R&D landscape. The United States leadership in global R&D and the technologies that come from those activities is not guaranteed, and simple solutions to maintaining or strengthening our competitive edge are hard to come by. Nevertheless, this Committee has proven tireless in its efforts to do just that.

Innovation and the economic activities that it drives are more than just a political buzzword. They are critical tools to economic revitalization, national security and environmental responsibility. They span the country and touch all aspects of American life and they underpin our ability to address global problems, maintain competitive advantages and strengthen alliances and trade relationships. For all of these reasons, we are here today to discuss the absolutely vital role the Department of Energy and national labs play as our nation's foremost federal R&D organizations in American competitiveness.

Given our Committee's focus, it may appear that federal R&D activities are limited to a short list of energy technologies, but I would like to paint a broader picture. We have a responsibility to think across the Federal Government when considering how to advance our research, development and commercialization agenda so that we can identify the strengths and weaknesses at various agencies. Starting with the Manhattan Project, the national labs and the early agencies that became the Department of Energy developed several proven models of basic research leading to applied projects. Other models of R&D were developed, including those that champion fundamental scientific research at universities like the National Science Foundation (NSF) or those models closely aligned with specific industries such as pharmaceuticals or defense R&D.

Over time, DOE's mission grew into a network with other federal research agencies in which the Department and labs provide both expertise and 28 user facilities, including to over 36,000 users annually, a number of whom are funded by the National Science Foundation, drawing on federal funding for equipment from lasers to particle accelerators and world's fastest computers. DOE and the labs have been able to tackle a broad variety of challenges facing the nations because they have continued to excel across the R&D spectrum from basic to applied research and commercialization. For example, just last week discoveries made by Dr. Chris Polly, a researcher at Fermilab in Illinois, and his international team of 200 colleagues may have turned the entire field of physics on its head. The Office of Science also directly funded university research of approximately $1 billion in Fiscal Year 2020. At the commercialization end, ARPA-E has just announced a new program investing $35 million in high potential methane emission reduction technologies. It is a critical set of solutions for domestic and international industries in the context of climate change. These advances have both increased the importance of DOE's role as a coordinating research agency and a platform for computational power, public research infrastructure, and a deep pool of experts around the country. Other research agencies may have a higher public profile like the National Institutes of Health (NIH), or a stronger relationship with the ultimate end users of technology it develops, like DARPA.

But DOE and the national labs excel at the diversity of research subject areas and the breadth of technological development they pursue. That said, we all recognize that the United States is not alone in the pursuit of technologies that will make or break the future. Friends and adversaries alike are either catching up or eating our lunch at several stages of technological investment and in many subject areas. Colleagues of ours have rightfully called attention to several technologies critical to our national security addressing climate change and our export potential.

Let me be clear: I fully support strengthening our domestic supply chains, expanding the portfolio of the technologies we are researching, enhancing their commercialization, and pursuing every opportunity to advance the United States' competitive advantages abroad. That will require a clear coordinating role and a responsible consideration of funding across the Federal Government. And I would argue that efforts to strengthen our R&D foundation and technology development ought to start with the Department of Energy and national labs. I will repeat that, I would argue that efforts to strengthen our R&D foundation and technologies development ought to start with the Department of Energy and national labs. We should not be reinventing the wheel or duplicating programs and missions, especially when we need to be inventing the newest and best technologies. As this conversation around the domestic R&D global competitiveness grows, I urge my colleagues to continue to stand strong in support of R&D funding and coordination led by the Department and its national labs.

Before I turn to Senator Barrasso for his opening statement, I would ask unanimous consent to submit two items to the record.

Senator BARRASSO. Without objection.

The CHAIRMAN. Without objection.

First, all 17 national laboratory directors submitted a letter to the Committee outlining the strengths of the national lab system with regard to key technology areas and in partnership with other federal research agencies.

[The letter from the directors of the national labs referred to follows:]

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April 13, 2021

The Honorable Joe Manchin
Chairman
Energy and Natural Resources Committee
United States Senate
304 Dirksen Senate Office Building
Washington, DC 20510

The Honorable John Barrasso
Ranking Member
Energy and Natural Resources Committee
United States Senate
304 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairman Manchin and Ranking Member Barrasso:

On behalf of the National Laboratory Directors' Council (NLDC) – comprised of the directors of the seventeen Department of Energy (DOE) national laboratories – we write in response to your recent request for technical assistance on the draft of the Endless Frontier Act.

We commend Majority Leader Chuck Schumer and Senator Todd Young for recognizing the critical role that innovation driven by federal investment in research and technology development plays in competing with China and ensuring U.S. leadership in key technology areas. Their efforts reflect the type of bold and inventive thinking needed to address U.S. international competitiveness and to deliver novel solutions to the challenges facing the nation.

Since their founding in the Manhattan Project, the DOE national laboratories have delivered scientific advances and technology solutions for the nation, while balancing the need for open, collaborative science with the imperative of national security, economic security, and technological superiority. The DOE national laboratories are mission-driven research and development organizations that reside in an important space, with a long-term perspective and operating across the full spectrum from fundamental to applied research to the demonstration and deployment of technologies. This makes them complementary to both academia, which focuses on fundamental research and the advancement of knowledge, and industry, which is primarily concerned with the development and application of research outcomes in the near-term. As such, we believe the DOE and its national laboratories can make significant contributions to out-competing China.

We recommend that the Endless Frontier Act or other related legislation embrace a broader approach to advancing the nation's international technology leadership and economic competitiveness by investing in and strengthening the entire U.S. innovation ecosystem, including the ongoing work and additional initiatives of DOE and the national laboratories across the Act's key technology focus areas. Specifically, we recommend a separate, substantial, targeted investment in research for DOE and the national laboratories to advance key technology areas in coordination and collaboration with the National Science Foundation (NSF), and to fund increased support for and access to world-leading user facilities stewarded by DOE and utilized by NSF-supported scientists to advance scientific discovery and technology development. We share the view that providing much greater resources across the innovation ecosystem is the best way to achieve the Senate's goal of bolstering our competitiveness with China, and indeed with the rest of the world. Our distributed, multi-agency, multi-stakeholder approach to science and technology has served the nation well throughout its history. This approach brings diverse viewpoints, wide ranging capabilities, creativity, and ingenuity to science and technology in a way no other country can match.

NSF, like DOE, is an essential component of the nation's innovation ecosystem and an important partner to the DOE and its national laboratories. NSF is the only federal agency charged with the promotion of scientific progress across all science and engineering disciplines. The research funded through its rigorous peer review process is vital to the public interest and has led to transformative discoveries that have reshaped our world. Through its sponsorship of cutting-edge, university-based research, NSF supports the education and training of the nation's scientists, engineers, and teachers and the next generation of new ideas.

Complementing these efforts, DOE assembles and nurtures multi-disciplinary teams of scientific experts to meet federal needs and address national priorities by attacking R&D challenges at scale. DOE does this by supporting university research, industrial partnerships, and a network of 17 national laboratories that are responsible for cutting-edge science and technology research and development. The national laboratories are also responsible for constructing and maintaining one-of-a-kind, world-class research capabilities that are leveraged broadly by over 36,000 university and industrial researchers every year.

For example, the DOE Office of Science maintains and operates 28 user facilities at its national laboratories across the country. These major pieces of scientific infrastructure range from advanced supercomputers and particle accelerators to large neutron and x-ray light sources and specialized facilities for nanoscience and genomics. These user facilities are vital tools of scientific discovery and provide unique and often world-leading capabilities. The National Synchrotron Light Source II at Brookhaven National Laboratory, for instance, is currently one of the brightest X-Ray Light sources in the world and enables discoveries in a broad range of fields, including biomedicine, energy storage and conversion, quantum technology, and molecular electronics.

DOE and the national laboratories provide access not only to these major scientific tools but to dedicated experts who help tens of thousands of researchers funded by NSF and other agencies, as well as industry users, conduct scientific experiments with these powerful tools. Access to these facilities is awarded based on merit review of proposals. Technical upgrades are underway at many of these facilities to ensure that they will remain at the international forefront. However, operations of these facilities are highly budget-constrained at the same time that they are in such high demand that they are already oversubscribed in most cases by a factor of two to five. The additional funding proposed for NSF as part of the Endless Frontier Act would place further demand on these valuable tools. DOE would require a complementary and commensurate investment in the tools, capabilities, and staff support for these user facilities to enable the greater volume of high-impact research and development envisioned by the Endless Frontier Act.

DOE and the national laboratories are also at the forefront of advancing emerging technologies, including both fundamental and use-inspired research and development of applied energy technologies. The national laboratories also maintain a complex of energy technology demonstration facilities, such as the Manufacturing Demonstration Facility at Oak Ridge National Laboratory and the Wind Dynamometer Test Facilities at the National Renewable Energy Laboratory, that are critical to the advancement and derisking of U.S. technology innovations.

Coordination between DOE and NSF is essential to leverage each agency's respective strengths to maintain U.S. leadership. In reviewing the key technology focus areas enumerated in the Endless Frontier Act, the National Laboratory Directors' Council identified significant DOE investments at national laboratories and universities in nine of the eleven focus areas. We would welcome an opportunity to discuss with you the full portfolio of these efforts and ways that the capabilities and expertise of the national laboratories should be leveraged to support increased investment in these areas. We include four illustrative examples here:

- In quantum computing and information systems, the national laboratories are leading five National Quantum Information Science Research Hubs – each with diverse members that include American industry, universities, and national laboratories – funded by DOE, thanks to bipartisan congressional support for the National Quantum Initiative and subsequent appropriations. These centers are part of a coordinated, multi-agency effort with the NSF and National Institute for Standards and Technology, and serve as an excellent example of a complementary, multi-agency approach.
- On high performance computing, semiconductors, and advanced computing hardware, the national laboratories operate two out of the top three of the world's fastest supercomputers with more coming online later this year and early next through the Exascale Computing Initiative. And by nature of their design, these exascale systems will also represent the most powerful artificial intelligence machines in the world. In addition to the supercomputers, the national laboratories have some of the world's leading experts in computer science and advanced mathematics, which is crucial to leveraging each new generation of bigger and better computing capabilities through advanced software development. This is a key area where DOE, through Office of Science and the National Nuclear Security Administration (NNSA), and the national laboratories have long maintained the delicate balance between the need for open science and imperative for national security as stewards of the nation's nuclear deterrent.
- In advanced energy, batteries, industrial efficiency, and materials science, DOE – across nearly its entire portfolio – is the lead agency for the nation in driving innovation through research and development efforts at national laboratories and universities in partnership with industry; capability development and stewardship, especially at the national laboratories; and supporting robust public-private partnerships.
- In biotechnology, genomics, and synthetic biology, DOE's national laboratories possess one of the world's greatest collections of research facilities, international scientific leadership, and other assets focused on non-human biology for energy, environmental sustainability, and biomanufacturing. The Joint Genome Institute at Lawrence Berkeley National Laboratory and the Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory are among the world's most sophisticated research facilities focused on biology by design to address climate change, clean energy, and environmental sustainability. These facilities are utilized annually by thousands of users and tens of thousands of data users. Over the past year the National Virtual Biotechnology Laboratory was rapidly organized to bring DOE and NNSA scientific user facilities, additive manufacturing capabilities, and high-performance computing to bear addressing the threat posed by COVID-19.

In regard to all the key technology areas, the DOE and its national laboratories have the talent and the mechanisms to analyze the dual use implications of new technologies, and the charge to alert government authorities and policymakers to over-the-horizon technical threats that may impact American lives and underpin future U.S. economic competitiveness. The NNSA has been analyzing and identifying threats for decades with respect to U.S.-developed nuclear materials and technologies. All national laboratories have been doing the same with respect to artificial intelligence, biotechnology, and high-performance computing. These at-the-ready capabilities can be expanded and re-tasked as necessary to address ongoing and

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emerging threats, and are vital to advance research frontiers in such a way as to assure our national security and economic competitiveness.

Finally, we recognize that the draft bill makes national laboratories eligible for grants from the new NSF directorate created by the bill. However, historically and currently, the national laboratories as Federally Funded Research and Development Centers are not considered eligible to apply for funding from the NSF, nor do we believe it is appropriate for national laboratories and universities to compete head-to-head for awards except through diverse, multi-institution consortia.

Thank you for requesting our input, and for your part in authorizing and overseeing the important work of the Department and our laboratories. Congress has made significant investments in DOE and the national laboratory complex that address most of the key technology areas outlined in the legislation. We look forward to working with you to ensure that DOE's national laboratories receive the resources necessary to execute additional work in support of the goals of the Endless Frontier Act while also maintaining its stewardship and mission obligations to DOE.

Respectfully,

Adam Schwartz
Director, Ames Laboratory
Executive Committee, NLDC

Paul K. Kearns
Director, Argonne National Laboratory
Executive Committee, NLDC (Ex Officio)

Doon Gibbs
Director, Brookhaven National Laboratory
Chair, NLDC

Nigel Lockyer
Director, Fermilab

John Wagner
Director, Idaho National Laboratory

Michael Witherell
Director, Lawrence Berkeley National Laboratory

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Director, Savannah River National Laboratory

Chi-Chang Kao
Director, SLAC National Accelerator Laboratory

Stuart Henderson
Director, Thomas Jefferson National Accelerator Facility

Secondly, former Secretary of Energy Ernest Moniz is currently testifying before the House Science Committee on the topic of innovation and given that Secretary Moniz has appeared before this Committee as well, I believe his written testimony will support our discussion of this topic going forward.

[The referenced testimony of former Secretary of Energy Ernest Moniz follows:]

Testimony of Secretary Ernest Moniz, CEO, Energy Futures Initiative
before the House Committee on Science, Space and Technology
April 15, 2021

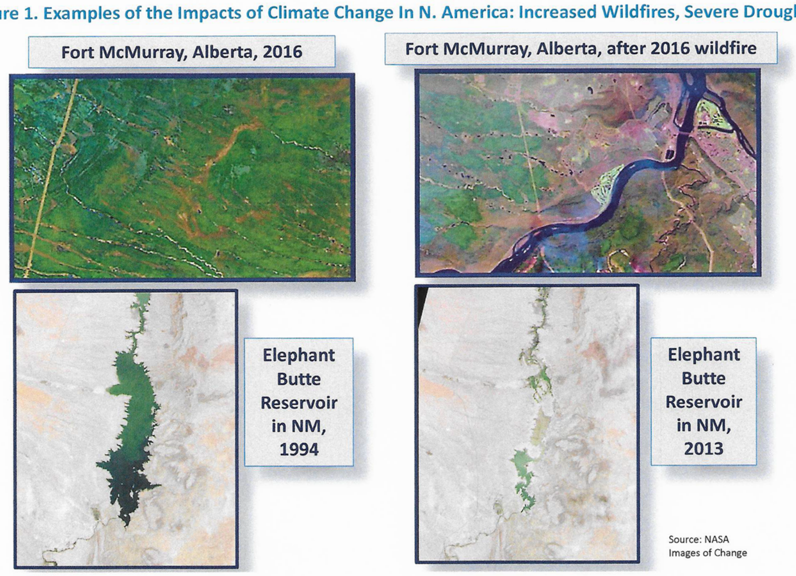
Madam Chair, Ranking Member Lucas, members of the Committee, thank you for the opportunity to testify before you today.

The US is approaching 600,000 deaths from the COVID pandemic. The loss of decades old businesses, millions of jobs, and the overall impacts of the pandemic on the US and global economy are without parallel in modern times.

At the same time, the world is facing another crisis of global and existential proportions: climate change. Its impacts and their growing severity are becoming increasingly clear. According to NOAA, 2011–2020 was the warmest decade on record for the globe, with a surface global temperature of 1.48°F above the 20th century average. Every month of 2020 except December was in the top four warmest on record for that month.

There are, as we have seen, a range of physical impacts of these temperature increases – rising sea levels, increased frequency and intensity of storms, increased drought, declining water supplies, melting glaciers, increased wildfires, greater extremes of both heat and cold. Figure 1 offers graphic pictures taken by NASA of the impacts of wildfires and droughts in North America. The science is clear, and the data are compelling—climate change is a major threat to our planet and to our way of life, and the clock is ticking.

Figure 1. Examples of the Impacts of Climate Change In N. America: Increased Wildfires, Severe Drought



The growing severity of these changes – and the urgent signals they are sending -- has not gone unnoticed by the world's nations. In 2015, 197 countries adopted the Paris agreement. According to the UNFCC, 191 countries have submitted their first Nationally Determined Contribution (NDC) and eight have submitted their second.[i] Importantly, since Paris, the number of countries that have implemented or are considering net zero emissions targets, now stands at 130, up from around 17 just two years ago.

This is true in the US as well, where the Biden Administration is setting us on a new and accelerated course towards an economy with net zero greenhouse gas (GHG) emissions by mid-century. The U.S. has rejoined Paris and within a matter of days, it is expected that the Administration will release an updated ambitious Nationally Determined Contribution setting a new interim target for GHG reductions by 2030. I applaud these actions and look forward to working on ways the US can meet these increased ambitions and to highlight these and other U.S. actions at COP 26 in Glasgow later this year.

Critical Context for Guiding Innovation Investments

There is a range of responses that are needed to address the climate crisis but today I would like to focus on one: the critical need for technology innovations to address both the growing impacts of climate change and the increased ambitions of most of the world's nations, including the United States. As the science of climate change has advanced and the changes in the impacts of climate become more manifest and severe, the Energy Futures Initiative's analysis has increasingly focused on those innovations that are central to any climate action plan that can succeed in reaching the aggressive—but essential—net-zero goal.

Before I discuss some of the innovations that will be key to deep decarbonization, I think it is important to place the associated investments in a larger context as we consider the portfolio of technologies needed to meet net zero targets by mid-century. These include: the changing risk profile; the growing interdependencies of critical infrastructures; the potential, indeed likely, changes in our work environment, post-COVID; the growing importance of supply chains; and regional differences and needs.

- ***The changing risk profile***. In the last two years, two of our largest states – Texas and California – have been devastated by the impacts of climate change. Wildfires in California forced the preemptive shutdown of large sections of the state's grid. Last August, a western US extreme heat wave forced rolling blackouts in California. More recently in Texas, the extreme cold snap left much of the state without power and heat. These and other events suggest that weather and other risk profiles that have guided infrastructure protection, development, and investments are no longer adequate for risk assessment, associated policy actions, and infrastructure investments in the future. Yesterday's weather is no longer a good guide for planning to meet tomorrow's weather extremes

  Late last month, the Financial Stability Oversight Council met; its agenda included a discussion of climate risk and the implications of this risk for the nation's financial systems. The SEC, Federal Reserve and CFTC are all analyzing options on disclosure of climate risks. The Federal Reserve is working to "...understand the potential implications of climate change for financial institutions, infrastructure and markets." These activities need to be supported by research to update climate risk assessments in order to better guide investment planning and disclosure requirements. These actions also reinforce the ESG focus of shareholders and institutional investors. Taken together, we anticipate profound shifts in corporate priorities in the direction of accelerating the response to climate change.

- ***The complex interdependencies of critical infrastructures***. Preliminary analysis of what went wrong in Texas, from a systems perspective, suggests that the natural gas, electricity, and water systems were all affected by the extreme cold and that their interdependencies were major contributors to the electricity crisis.

This is not surprising. The first installment of the Quadrennial Energy Review, released in in 2015, included a section specifically focused on the 2011 cold snap in Texas and New Mexico, emphasizing the growing interdependencies of the electricity and natural gas infrastructures, borne out by the events in Texas 10 years later (see Text Box 1).

Text Box 1. QER 1.1 Highlighted Gas/Electric Infrastructure Interdependencies

The Big Chill: A Disruptive Event Made Worse by Infrastructure Interdependencies[1]

The "Big Chill" of 2011 illustrates the complicated relationship between natural gas and electric power, which had compounding effects during a period of extreme weather.

During the first week of February 2011, the U.S. Southwest was hit by an arctic cold front that was unusually severe in terms of its low temperatures, gusting winds, geographic extent, and duration. From January 31 to February 4, temperatures in Texas, New Mexico, and Arizona were the coldest experienced within the region since 1971. Dubbed the "Big Chill" in the media, it overwhelmed the routine preparations for cold weather that had been put in place by electric generators and natural gas utilities located in those states.

Within the Electric Reliability Council of Texas (ERCOT) Interconnection, starting in the early morning hours of February 2, the cold temperatures and wind chill caused a significant number of outages at generating plants, with approximately one-third of the total ERCOT generating fleet unavailable at the lowest point of the event. With electricity demand soaring because of the cold weather, ERCOT and some utilities in New Mexico instituted rolling blackouts to prevent collapse of their electric systems. For the Southwest as a whole, 67 percent of electric generator failures (by megawatt-hour) were due directly to weather-related causes, including frozen sensing lines, frozen equipment, frozen water lines, frozen valves, blade icing, and low-temperature cutoff limits on equipment.

Gas producers and pipelines were also affected in Texas, New Mexico, and Arizona. Natural gas production was diminished due to freeze-offs and the inability to reach gas wells (due to icy roads) to remove produced water and thereby keep them in operation. When rolling electricity blackouts hit gas producers and gas pipelines, it had the effect of causing further losses to natural gas supply. The ERCOT blackouts or customer curtailments caused or contributed to 29 percent of natural gas production outages in the Permian Basin and 27 percent of the production outages in the Fort Worth Basin, principally as a result of shutting down electric pumping units or compressors on gathering lines. As a result of all these factors, natural gas deliveries were affected throughout Texas and New Mexico. More than 30,000 customers experienced natural gas outages at some point during this period.

The majority of the problems experienced by the many generators that tripped, had their power output reduced, or failed to start during the event were attributable, either directly or indirectly, to the cold weather itself. However, at least another 12 percent of these problems were attributed afterward to the interdependencies between gas and electricity infrastructures (such as lost electricity generation due to natural gas curtailments to gas-fired generators and difficulties in fuel switching).

[1] Federal Energy Regulatory Commission and North American Electric Reliability Corporation. "Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011: Causes and Recommendations." August 2011. http://www.ferc.gov/legal/staff-reports/08-16-11-report.pdf. Accessed February 2, 2015.

- ***The growing importance of supply chains***. Increased electrification, new clean energy technologies, LNG exports to allies, and COVID have raised issues about the security of global supply chains and the need to focus on creating, building, and reinvigorating domestic options. Increased electrification and the buildout of transmission lines and variable renewable generation technologies will, for example, mean dramatic increases in demand for steel, EV battery manufacturing, the mining, processing, and refining of key metals and minerals including lithium, cobalt, manganese, and nickel, and cathode and anode production. Also, this demand growth is not occurring in a vacuum. Net zero targets are increasing demand—and competition—for steel, EVs, batteries, and other key materials and technologies around the world.

The need to address these issues was underscored by President Biden's Executive Order 14017, America's Supply Chains, which notes that "More resilient supply chains are secure and diverse—facilitating greater domestic production, a range of supply, built-in redundancies, adequate stockpiles, safe and secure digital networks, and a world-class American manufacturing base and workforce. Moreover, close cooperation on resilient supply chains with allies and partners who share our values will foster collective economic and national security and strengthen the capacity to respond to international disasters and emergencies."

- ***Changes in the work environment, post-COVID.*** While no one knows for certain how the unprecedented experience of the pandemic will affect the work environment of the future, it appears likely that there will be dramatic increases in the numbers of people working from home. This could have significant implications for energy needs and the associated infrastructures to support the changed workplace.

First and foremost, it could require increased demand for reliable and resilient electricity supplies as productivity will be directly linked to power availability. It may also lower energy demand for transportation at the same time it could increase residential electricity demand; peak electricity demand profiles could change. In addition, it would require universal access to broadband to ensure all Americans have equal workplace flexibility options. The COVID crisis drove this point home: children without access to broadband could not "go to school". Businesses without access to broadband couldn't meet customer needs. Finally, the increased use of broadband and the internet to conduct business could increase concerns about cyber-security. Innovation investments should consider this changing profile and address these needs. An overarching point: continued electrification of the economy ups the ante for reliability, resilience, security and power quality of the electric grid.

- ***Regional differences and needs.*** Last, and perhaps most important for the members who represent varied constituencies across the country, the resources, infrastructures, emissions profiles, innovation, and policy needs vary greatly by region of the country—a "one size fits all" approach will likely impede, not accelerate progress towards deep decarbonization. EV charging infrastructures will, for example, look very different in both rural and urban areas, where the typical "suburban EV model mindset" and its associated infrastructure will have little relevance to densely populated cities and sparsely populated regions of the country. Industrial centers in the U.S. will have ongoing need for high quality process heat that cannot easily be provided by electricity. Many regions have sequestration options, some do not. Offshore wind resources are clearly available only to those regions with coastlines, and onshore wind resources vary greatly across the country as do solar resources. They also have large seasonal variations.

The Need for a Decade of Super-charged Innovation

Energy innovation is the essence of America's security and strength. Our ability to innovate is at the heart of American economic success and optimism. It is essential for national security, addresses complex societal challenges and improves our quality of life. It is critical for addressing the existential threat of climate change. Central to U.S. leadership in innovation is our unparalleled innovation ecosystem which includes the Federal, state, local and tribal governments; national laboratories; research universities; the private sector; nonprofits and philanthropies

Several groups, including the American Energy Innovation Council comprised of CEOs of large American companies, have argued for tripling federal clean energy investment. The Biden Administration has proposed an even more ambitious agenda—the President's request for FY 2022 discretionary funding includes more than $10 billion, a 35 percent increase over FY 2021, for clean energy innovation across all non-defense agencies. Further, as stated in the budget summary, "The 2022 discretionary request puts the Nation on a path to quadruple clean energy research Government-wide in four years."[1] The federal energy innovation portfolio—indeed the portfolio across the entire innovation chain—needs to be "all of the above" to match time scales and geographies and to emphasize optionality. History shows that we achieve better results when flexible innovation pathways are favored over planned, prescriptive outcomes.

This broad approach is critical as we accelerate clean energy innovation investments – both public and private -- over the next decade or so. Maximum optionality and flexibility will be needed to address the needs of different regions and of all end use sectors—including the industrial, heavy transportation and agricultural sectors that are hard to decarbonize. Breakthrough technologies will be needed.

Innovation can also drive job creation, which is essential as we come out of the COVID crisis with a need to create millions of good jobs. These are bipartisan opportunities to create clean energy jobs and strengthen our country, where coalitions — labor and business, environmental groups and financial institutions, religious and military leaders, public and private sectors, Republicans and Democrats, and others — are needed to accelerate legislative solutions to the climate challenge.

[1] U.S. Office of Management and Budget, Letter from Acting Director Shalanda D. Young to Senate and House Leadership, April 9, 2021.

Accelerating this transformation, however, will not be easy. U.S. energy systems are highly capitalized and provide essential services. making them risk averse and prone to considerable inertia. This creates an inherent tension between the energy incumbents and the technology disruptors; mitigating this tension through innovation, thoughtful policies, and creating clean energy job options is essential for a more rapid transition to deeply decarbonized energy systems and end use sectors.

Innovation is at the Core of Climate Change and Infrastructure Modernization. As noted, there will be no single nor simple solution to meet net zero emissions. While the key technological near-term strategies to move towards net zero may be generally understood (policy support is a separate and less clear-cut issue), many that may be currently available could benefit from further improvements in performance and cost. Also, many of the technology solutions needed to meet mid-century targets are not yet available, a conclusion specific to California that was made in the EFI study, *Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California,''* released in May, 2019.

Electricity storage is a case in point. Deployment of electricity storage systems is only in its earliest stage. Current commercial battery storage technology typically provides from 4-6 hours of storage; other options may provide longer duration storage but are site-specific, limited by geography or geology. Large scale deployment of intermittent carbon free electricity generation will require significant levels of longer duration storage capable of meeting daily, weekly, and even seasonal variations. The 2019 California study illustrates the challenges associated with limited-duration storage, seen in Figure 2.

Figure 2. California Wind and Solar Generation for Each Day of 2017, CA Installed Storage Capacity, 2019

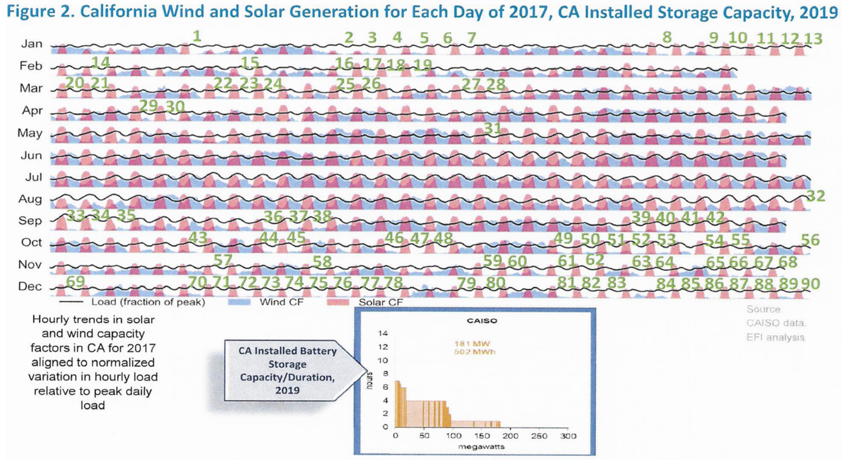


Figure 2 shows the hourly wind and solar generation for every day in 2017. Numbers in green count the days in the year where there was little to no wind generation in the state. The inset shows the installed battery storage capacity and duration in California which is currently insufficient to provide longer duration storage during multi-day periods with little to no wind generation.

The recent *Clean Energy Innovation Report* from the International Energy Agency provides a global context for immediate action on clean energy investment. The report emphasizes that while energy efficiency and renewable energy will be crucial, they are not sufficient to meet net-zero climate goals, especially in sectors like heavy industry and transportation.

The IEA Report also estimates that, on a global level, at least 40 percent of emissions reductions to reach net zero will rely on technologies not yet at commercial scale—including known technologies such as end-use electrification, CCUS, hydrogen, and bioenergy. In the study, IEA also stresses that action is necessary immediately because past innovations, such as LEDs and lithium-ion batteries, took decades to reach full commercialization, and some energy-consuming infrastructure operates on refurbishment cycles of 25-30 years.

There is also a large body of analytical evidence about the need for increased *national* investment – both public and private - across the full spectrum of energy innovation, from use-inspired fundamental research through demonstration and initial deployment. Various metrics have been used to assess the adequacy of investment in energy innovation. The 2019 Report by EFI and IHS-Markit, *Advancing the Landscape of Clean Energy Innovation,* estimated that global private R&D spending in the energy industry is substantially lower, both in dollars and in share of revenue, than in other major industries.

Looking at trends in government investment, federal energy R&D spending has been decreasing as a share of GDP. Federal energy R&D spending also lags other areas of federal R&D. A recent study by Columbia University Center for Global Energy Policy, for example, noted that federal energy R&D spending is less than one quarter the level for health care R&D and less than 10 percent of national defense R&D spending.

These issues have been documented in other studies as well, and the resulting recommendations have been clear and consistent. Also, the American Energy Innovation Council (AEIC) noted that government investment fills an essential niche by funding innovation where "the private sector cannot or will not."[2]

There is significant consensus from these and other reports on recommendations for federal energy innovation support that include:

- Expand the federal government's innovation role beyond early-stage R&D to fund demonstration, as well as establish complementary programs to promote deployment
- Fund new or vastly expanded innovation programs in key breakthrough technology areas
- Improve coordination across the federal government and expand the decarbonization innovation mission beyond DOE
- Harness the full range of tools for federal support, such as loan guarantees, financing support, tax credits, and procurement
- Create programs that can unlock funding from the private sector and collaborations that bring together public and private innovation resources
- Collaborate with state, Tribal, and local governments to support regional innovation, in many cases building on DOE national laboratory support
- Build on and supercharge successful innovation structures like ARPA-E, DOE Innovation Hubs, and Energy Frontier Research Centers

As Secretary, I led the effort to develop Mission Innovation, a collaborative commitment by 24 countries as well as the European Union to double the level of public investment of national governments in clean energy innovation over a five-year period. Mission Innovation was highlighted by national leaders at the first day of COP-21, a key companion effort to support the Paris Agreement. The Trump Administration did not follow-through on that commitment, and instead sought to cut DOE applied energy R&D programs dramatically in successive budget proposals over the past four years. Fortunately, Congress rejected those proposals and instead provided sustained growth in the DOE energy investment portfolio in the face of these headwinds, but at a slower pace than envisioned in the Mission Innovation commitment. As the most recent Mission Innovation scorecard shows (Figure 3), the U.S. public investment increased by over 43% over the first four years of Mission Innovation, but at a slower pace than 15 of the 24 Mission Innovation countries, including China.

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[2] American Energy Innovation Council, *Energy Innovation: Fueling America's Economic Engine* (Washington, D.C., 2018)

Figure 3. Progress of Mission Innovation Countries/EU on 2015 Commitment to Double National Investment in Clean Energy Innovation Over Five Years

Country	Progress toward goal
Norway	201%
Netherlands	185%
Japan	178%
UK	167%
Mexico	162%
Chile	83%
Austria	83%
Indonesia	82%
Canada	77%
Denmark	75%
South Korea	71%
Finland	63%

Country	Progress toward goal
Germany	63%
Sweden	60%
China	52%
United States	43%*
EU	41%
Australia	36%
Brazil	34%
India	26%
UAE	22%
Saudi Arabia	20%
France	17%
Italy	14%

MI Major Focus Areas

- Smart grids
- Off-grid electricity access
- Carbon capture
- Sunlight to fuels/storage
- Clean energy materials
- Affordable heating/cooling of buildings
- Renewables and clean hydrogen

*Morocco is newest member. It and US did not report totals, US percentage is an estimate from EFI analysis

Successful innovation requires sustained multi-year investment, and action by the Administration and Congress to revitalize and enhance the U.S. commitment to Mission Innovation. As part of this effort, the current seven focus areas of Mission Innovation noted in Figure 3 also should be expanded to include emerging promising technologies for carbon dioxide removal and advanced nuclear fission and fusion energy technologies.

A robust Mission Innovation program will not only be essential to any new agreement that will emerge at COP-26 in Glasgow, but also will serve to strengthen our global energy security posture. In 2014 after the Russian incursion in Ukraine, as Secretary I led an effort to develop the "G-7 Energy Security Principles" to move the U.S. and its allies off the decades-old oil-centric definition of energy security. The new, modernized view of energy security incorporates conventional energy as well as clean energy risks and, for the first time, formalizes the geopolitical security risks of climate change. These principles were adopted by G-7 energy ministers in Rome and by G-7 and EU leaders later that year in Brussels. The modernized principles, summarized in Figure 4, acknowledge the importance of clean energy as an enabler of energy security and underscore the high value of clean energy innovation as an enduring contributor to global security (highlighted in green)

Figure 4. Energy Security Principles Adopted by G-7/EU Leaders, 2014

- Flexible, transparent and competitive energy markets, including gas markets, should be developed.
- Infrastructure modernization will improve energy system resilience. Promoting supply and demand policies will help withstand systemic shocks.
- Energy fuels, sources and routes should be diversified and development of indigenous sources of energy supply should be encouraged.
- Reducing our greenhouse gas emissions and accelerating the transition to a low carbon economy are key contributors to enduring energy security.
- Energy efficiency in demand and supply, and demand response management should be enhanced.
- Deployment of clean and sustainable energy technologies and continued investment in research and innovation should be promoted.
- Emergency response systems, including reserves and fuel substitution for importing countries, should be put in place to manage major energy disruptions.

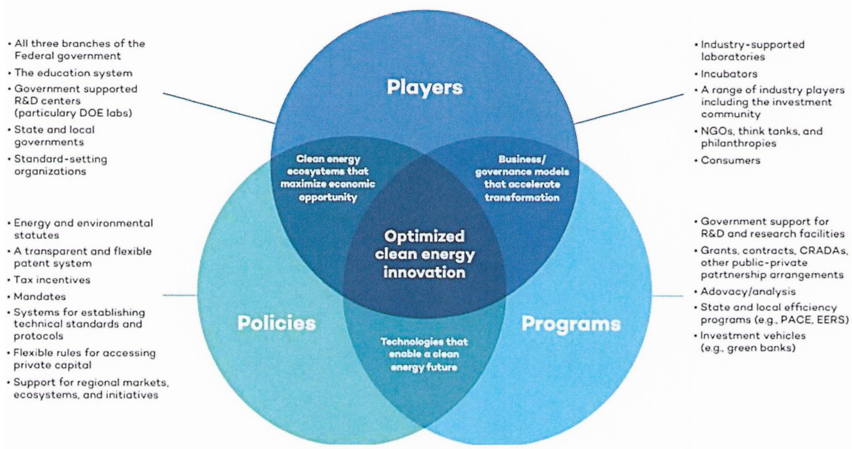
Adapted from Joint Statement, Rome G7 Initiative for Energy Security, May, 2014

Portfolio Elements for a Supercharged Innovation Program

The U.S. clean energy innovation system is unparalleled. It includes extensive collaboration among all levels of government, national laboratories, research and academic institutions, and the private sector. To ensure the U.S. economy reaches net zero carbon by midcentury, there must be a supercharging of clean energy innovation. This means increased, and more targeted, public, and private sector investment and close alignment across all stages of innovation—from basic research through demonstrations and deployment.

Federally supported and led energy innovation research depends on close alignment of activities across agencies, regardless of appropriated amounts. A key focus is the Department of Energy, which has historically administered the lion's share of Federal investment in clean energy innovation. Other agencies, however, have and must continue to play a significant role in clean energy innovation. These include the National Science Foundation (NSF), Department of Defense (DOD), the Department of Transportation (DOT), and the Department of Agriculture (USDA); portfolios at these agencies have different areas of focus—each important to support the overall innovation system. Figure 5 depicts how the alignment of key players in both the public and private sector, policies and programs can help optimize clean energy innovation.

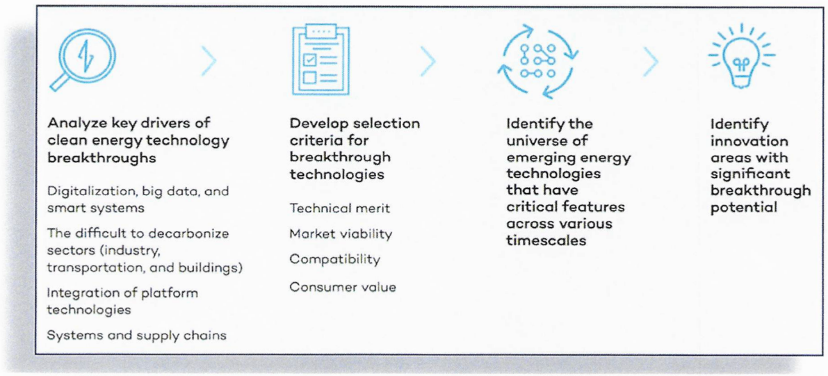
Figure 5. Aligning the Key Players, Policies, and Programs Can Optimize Clean Energy Innovation



At the core of success in developing the technologies and systems needed to reach a carbon neutral economy by midcentury is a robust clean energy innovation portfolio. Developing a portfolio based on any single variable, such as cost, may be inadequate. Some sectors, such as aviation and manufacturing, are more difficult to decarbonize than others but will require significant attention, innovation spending, and other types of policy, regulatory, and business model support. There are also significant systems integration needs that cannot be met if innovation investments are too narrowly focused.

Breakthrough Technology Evaluation Criteria. *Advancing the Landscape of Clean Energy Innovation* study described the importance of a systematic method for planning a comprehensive RD&D portfolio. The report provided a four-step methodology for identifying breakthrough technologies to address national and global challenges and help meet near-, mid-, and long-term clean energy goals as seen in Figure 6.

Figure 6. EFI's Four-Step Methodology for Identifying Breakthrough Technology Areas[3]



The following are expanded definitions of these technology selection criteria:

- **Technical Merit** includes energy or environmental performance, especially GHG reduction, leading to systems-level performance improvements. It also includes enabling innovations or knowledge and heuristic gains for cost, risk, and performance across a variety of technologies or systems.
- **Market Viability** includes manufacturability at scale with adequate and secure supply chains; a viable cost-benefit ratio for providers, consumers, and the greater economy; maturity to support very large scale-up; economic and environmental sustainability from a life-cycle perspective; significant market penetration; and revenue generation.
- **Compatibility** includes potential to interface with a wide variety of existing energy infrastructures (interoperability); potential to adapt to a variety of possible energy system development pathways (flexibility); potential to expand or extend applications beyond initial beachhead applications (extensibility); and the ability to minimize stranded assets.
- **Consumer Value** takes into consideration potential consumer preference issues, such as expanded consumer choice (by facilitating the introduction of new or improved products and services) and ease of use.

Shortlist of Breakthrough Technology Areas. The EFI/IHS-Markit study identified five broad technology areas deemed to have high breakthrough potential, including:

1) advanced battery and long-duration energy storage technologies;
2) Deep decarbonization: large scale carbon management;
   a. Carbon capture, use and storage at scale
   b. Sunlight to fuels
   c. Biological sequestration
3) Technology applications of industry and buildings as sectors that are difficult to decarbonize;
   a. Hydrogen

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3 https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5e56b4e66212a045e9892505/1582740734147/Advancing+the+Landscape+of+Clean+Energy+Innovation.2+2019.pdf Page 78

    b. Advanced Manufacturing Technologies
    c. Building energy technologies
4) advanced nuclear reactors;
5) platform technologies, such as AI, machine learning and big data analytics;
6) Systems: electric grid modernization and smart cities.

The process of technology innovation is dynamic, and over the past several years several other new technology areas with breakthrough potential have emerged including:

1) Technological and technologically enhanced carbon dioxide removal;
2) Nuclear fission micro-reactors; and
3) Nuclear fusion technologies

Progress is being made. The Energy Act of 2020 marks a significant move to advance and accelerate the energy innovation agenda. The Act also authorized a series of measures to improve DOE management of the innovation process. In addition, the Act authorized new energy RD&D efforts in seven major titles that largely mirror the breakthrough technology areas identified above, including:

- Energy Efficiency
- Nuclear Energy
- Renewable Energy and Storage
- Carbon Management
- Carbon Removal
- Industrial and Manufacturing Technologies
- Critical Materials; and
- Grid Modernization

The Energy Act of 2020 also emphasized the importance of federal support for demonstration projects as a critical need in the end-to-end innovation (i.e., RD&D) cycle for next generation clean energy technologies. Government policies and programs that enhance learning across the innovation chain should be built out and encouraged. The authorizations in the Energy Act were accompanied by increased appropriations to translate these directives into action. For example, more than $400 million dollars was appropriated to demonstration projects across these key technology portfolio elements, including $250 million for the Advanced Reactor Demonstration Program; and $115 million for SMR development, design, and demonstration. The consideration of the supply chain and jobs needs—both are key to later stages of the innovation system— promote long-term success. Wind energy programs, for example, received significant funding for offshore and distributed systems, advanced manufacturing of component parts, grid integration, and job training.

Enabling Platform Technologies. The 2019 EFI/HIS-Markit study also identified the importance of so-called platform technologies as an enabler of energy technology innovation. The rapid development of digital, data-driven, and smart systems—largely from outside the energy sector—has unlocked the potential of other platform technologies that could be scalable across the entire energy value chain. Key platform technologies include:

- Additive manufacturing, enabling more efficient and customized fabrication of products at smaller production scales;
- Materials by design, utilizing computational methods to enable more rapid prototyping of materials to meet specialized requirements;
- Artificial intelligence and big data analytics to provide new insights into many applications ranging from optimization of industrial processes to improved reliability of the electricity grid;
- Genomic science and synthetic biology, to develop new biomass energy sources, enhanced carbon capture pathways and to substitute biological for chemical processes; and
- Blockchain, to enhance the integrity of databases and provide better tracking of transactions throughout the supply chain.

A greatly enhanced focus on these platform technologies could be led by NSF, with important contributions from DOE, DOD Commerce/NIST, HHS/NIH and others in a whole of government approach.

Priority Areas of Emphasis. Federal agencies must work closely with the private sector to ensure the evolving policy environment, climate science, and financial and investment trends factor into the innovation programs and the technology portfolio. RD&D areas that merit additional support include cross-cutting technologies that reduce emissions in multiple sectors and strengthen the foundation of the innovation infrastructure. A few examples are: clean hydrogen; sustainable supply chains; climate risk analysis tools; and carbon dioxide removal.

Clean Hydrogen. Hydrogen is a clean energy carrier with multiple applications across every sector of the economy. Clean hydrogen could play an essential role in a low carbon economy as a zero-carbon "fuel" and was identified as one of ten technologies with significant breakthrough potential in *"Advancing the Landscape of Clean Energy Innovation."*

EFI analysis in 2019 also concluded that hydrogen was one of four cross-cutting clean energy pathways that could help California meet its mid-century net zero targets. The Energy Act of 2020 provides a strong foundation to build a robust hydrogen ecosystem in the United States through appropriations to study the benefits of blue hydrogen, research methods to reduce hydrogen transportation costs, and advance fuel cell technologies, among others.

There is significant interest among investors, utilities, oil and gas companies, and heavy industry to be part of the hydrogen solution. Opportunities for clean hydrogen end uses include industrial processes, heavy transportation, and power generation. Hydrogen from natural gas steam methane reforming (SMR) processes are already mature and meet almost all current domestic hydrogen demand. Producing "blue hydrogen" by capturing the carbon emitted via this hydrogen production approach is an off-the-shelf clean hydrogen solution. Using clean electricity to produce "green hydrogen" is also commercially available but requires further innovation to reduce costs.

As with carbon capture and sequestration, large hydrogen users may have the business expertise and capita availability to support an end-to-end hydrogen supply chain for their own uses. For clean hydrogen to scale however, new infrastructure investments will likely be required to enable market hubs where severa producers and consumers are co-located and benefit from economies of scale.

The infrastructures needed for hydrogen market formation tend to be highly regional. Potential large-scale consumers, such steel, and power generation, tend to be in close-proximity, and are already supported by pipelines, power lines, roads, and other infrastructures needed for the clean energy transition. Finding similar synergies with other infrastructure needs for achieving deep decarbonization, including carbon capture and storage from a range of facilities, could lower the overall development costs of a hydrogen-fueled economy at the same time they provide pathways for a net zero future. These potential "hubs" could be formed in regions where various users of hydrogen across industrial, transport and energy markets are co-located and could benefit from shared infrastructure.

Targeted additional support would allow the U.S. to accelerate the development of clean hydrogen as a versatile energy source and the resultant decarbonization benefits. Regional-based studies of the range of hydrogen production pathways and viable market and regulatory structures is an important area that deserves additional support. Green hydrogen production pathways, which use clean electricity resources to produce hydrogen, are an important option for regions that lack suitable geologic storage capacity. Deploying hydrogen transport, storage, and fueling infrastructure will be critical to realize U.S. decarbonization goals, and region-specific plans will likely be needed to account for variable regional aspects such as geological storage potential and energy demand. A transition to clean hydrogen will also require preparing a workforce trained to handle hydrogen from production through end-use and ensuring that such jobs provide competitive wages. Finally, a national, economy-wide roadmap for the deployment of hydrogen across all relevant sectors should be developed, establishing multi-year goals and R&D initiatives focused both on technology advances and accelerating market penetration.

Sustainable Supply Chains. Supply chain issues of new clean energy technologies must be evaluated and factored into policy plans. Favoring certain clean energy pathways without considering the potential material and process limitations could delay or hinder U.S., and global, decarbonization efforts.

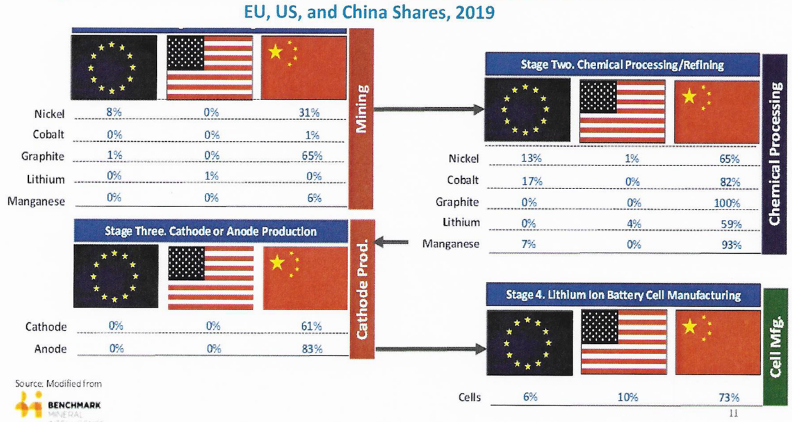
Policies and programs that could enhance US capacity in these areas include:

- protection of global supply chains for minerals/metals needed for wind, solar and batteries;
- support for innovation to support new domestic, environmentally responsible, net-zero mining activities for key minerals/metals, including associated infrastructures;
- an increase in the capacities, capabilities, and associated infrastructures needed for key mineral chemical processing/refining and battery manufacturing;
- significant recycling programs for key metals and minerals; and
- research into substitutions for key minerals by earth-abundant metals and minerals.

Much of the innovation in this area has been led by the private sector, and additional private investment in these areas is much needed. A key requirement to foster increased private sector innovation is the protection of intellectual property rights. Federal policy to protect the rights of innovators has its roots in the U.S. Constitution, which calls for the government "to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." This principle was recently tested in the dispute between LG Energy Solutions (LGES) and SK Innovation (SKI) over the misappropriation of proprietary LGES EV battery trade secrets by SKI and destruction of pertinent records. Fortunately, the Biden Administration stepped in to facilitate a settlement between the two companies that maintained the integrity of IP protection policy while enabling the expansion of domestic manufacturing of EV battery systems and protecting jobs to support the electrification of the U.S. light duty vehicle market.

Figure 7 underscores the need for innovation throughout the supply chain for the metals and minerals supply chain for EV battery manufacturing. The heavy reliance on foreign supply at key points in the supply chain point to the need for RD&D and associated deployment policies to support net-zero domestic mining, chemical processing and refining, and manufacturing of electric vehicle lithium-ion batteries.

Figure 7. Select Process for Key Metals and Minerals Needed for EV Battery Production: EU, US, and China Shares, 2019



Title VII of the Energy Act of 2020 promotes a robust effort to rebuild domestic supply chains, emphasizing responsible production and efficient use, recycling, and development of alternatives for critical metals and minerals. In particular the establishment of a robust program for assessment of critical metals and minerals is an essential first step. The Act also authorizes DOE to conduct a comprehensive program of RD&D as well as commercial application for critical materials, including development of alternatives, recycling and efficient production and use. These efforts should expand to include all materials vital to the clean energy transition. Onshoring offshore wind supply chains, for example, including raw material extraction, manufacturing, and final assembly could generate thousands of good jobs that would generate significant regional economic activity.

New Climate Risk Frameworks. While Earth has seen major climate variation over its history, the pace of change today is well beyond that attributable to natural phenomena and is driven by human activity, especially from energy. The UN's 2019 Climate Action Summit brief noted that the last four years were the four hottest on record, and winter temperatures in the Arctic have risen by 3°C since 1990. The growing intensity and frequency of floods, hurricanes, and droughts across the country and the world have underscored both the ferocity and costs of a changing climate. As noted, a recent example is the winter storm in mid-February 2021 that affected large regions of the southern U.S., including Texas, with sustained subzero temperatures and snow. In Dallas, in February temperatures were -2 degrees F, while the average low for this time of year was around 40 degrees. Because two-thirds of Texans rely on electric heating, this led to a surge in electricity demand throughout the state of about 20 GWs, or one-third of the winter peak, far exceeding ERCOT's worst case planning scenario, based on the 2011 winter storm. In other words, we can no longer look at the past to predict the future.

It is critical that we develop a new, flexible climate risk profile for energy systems and the broader economy, including the associated analytical tools. This is an area that needs significant innovation investments in new models, techniques, and approaches for considering climate change-based risk into the system. It is critical that multi-agency efforts, with support from universities, the national labs, and other research institutions continue to develop tools, programs, and partnerships that closely monitor climate conditions, feeding into decision making processes in both the public and private sectors. The risk profiles need to be developed with regional granularity not just for polar vortices but for the entire spectrum of weather and other climate change extremes.

Carbon Dioxide Removal. CDR is an essential complement to CO2 emissions reductions, and a critical part of achieving net-zero emissions goals and subsequently net-negative emissions, thereby providing the opportunity to reverse some of the effects of historical GHG emissions. In EFI's 2019 report *Clearing the Air*, EFI outlined a 10-year, $10.7-billion RD&D program to bring more CDR approaches to deployment readiness—a necessary step to scaling up CDR to the point where it can make a meaningful difference. We believe that CDR is a necessary and material contributor to any successful pathway to net zero, and certainly for achieving a net negative emissions economy.

The Energy Act of 2020 establishes a broad-based CDR RD&D program to "...test, validate, or improve technologies and strategies to remove carbon dioxide from the atmosphere on a large scale." The Act also established prize program for direct air capture and authorized the Secretary of Energy to establish an interagency task force and report to Congress on additional CDR measures. These provisions track closely with the EFI Report recommendations. In addition, Congress made a historic investment in CDR RD&D in the December omnibus, with appropriations totaling over $90 million for RD&D on technological and technologically enhanced natural CDR pathways.

A significant increase in appropriations will be needed in future years to reach the funding levels recommended by the 2018 National Academy of Sciences Report and the 2019 EFI Report. Furthermore, current authorization and appropriations for CDR emphasize DOE programs for direct air capture as the principal CDR pathway. Additional emphasis should be extended to other CDR pathways, and other federal agency roles, including bioenergy with carbon capture (BECCS), and bioengineered plants, forestry, and soil pathways (with USDA); in situ and ex situ carbon mineralization (with Interior and EPA); and ocean-based CDR involving both biological and chemical methods (with NOAA). In December 2020, EFI issued a series of three supplemental reports on terrestrial CDR, oceans-based CDR and carbon mineralization.[4]

Targeted pilot testing and demonstration programs will be a critical element for assessing the feasibility and suitability of CDR for large scale deployment. EFI proposed a competitive, technology-neutral demonstration projects fund in *Clearing the Air*. And while the extension of the 45Q tax credit in the Energy Act of 2020 was critical to provide necessary incentive for deployment of both CDR as well as carbon capture, utilization and storage (CCUS) from point source emissions, proposals for expanding 45Q, enhancing its credit for CDR projects, and new tax credits for natural CDR pathways such as expanded tree-planting should be further explored.

Cyber-Security. Ensuring cybersecurity must be a fundamental consideration when modernizing and expanding U.S. energy infrastructures. The modern energy system—including the electric grid, natural gas systems, on-road and air transport, and manufacturing—will become increasingly dependent upon cyber-physical systems. As the energy system becomes smarter through the integration of information and operational technologies, the risks posed by cyber-attacks will increase.

There are, however, also opportunities to engineer cybersecurity into the future energy infrastructure in a way that supports decarbonization, operational resilience, and security. This will include developing intrusion detection systems into critical components, expanding our capability to monitor and track the supply chains for critical components, embedding cybersecurity into training across the entire workforce, building on our strong information sharing programs between the government and private sector and among industry itself. The recently revealed SolarWinds attack shows how cybersecurity must be applied along the entire supply chain for infrastructures. These and other measures should be integrated into how we build energy infrastructure in the United States.

Implementation Framework for a Super-Charged Clean Energy Innovation Portfolio

The architecture and processes for implementation of a federal energy innovation investment program are as important as the content of the portfolio itself. Drawing upon my experience in academia, government and now in the private sector, I offer several general principles for consideration.

First, innovation investment programs should build upon and better integrate the existing unparalleled innovation capacity in the U.S. across private industry, universities, research institutions, entrepreneurs and federal, state and local government entities. Stepping up the pace of energy innovation requires building upon the collaborative strengths of this innovation ecosystem. Increased federal investment in innovation can best accelerate the clean energy transition by leveraging all of the players into closer alignment. This can be accomplished through federal policies that encourage public-private partnerships, formation of regional innovation ecosystems and alignment of innovation investment with market formation policies.

The private sector is central to clean energy innovation, providing entrepreneurial vision, channeling financial resources, and connecting innovation to the rest of the energy system and the economy. The private sector is not only a key player in innovation, but also is key to testing and early adoption of innovations emerging from government and academia. Public private partnerships, leveraged by federal cost sharing and other policy initiatives, can expand and accelerate the ability of the private sector to deliver innovative energy products and services to consumers.

States, Cities and Tribal governments play a very important role in the energy innovation process, particularly as supporters of initial commercial adoption of new energy technologies and products. Expanded policy innovation in state electricity and natural gas regulatory practices also could play an important role in accelerating energy innovation.

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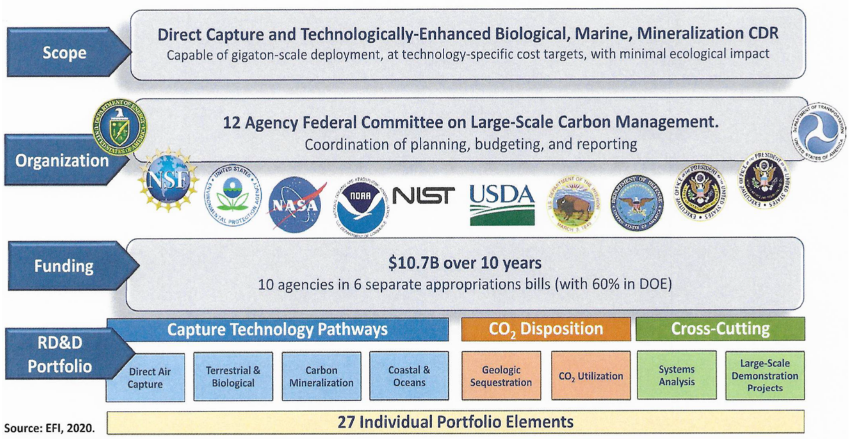
[4] The three reports are: *From the Ground Up: Cutting-Edge Approaches for Land-Based Carbon Dioxide Removal; Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments; and Rock Solid: Harnessing Mineralization for Large-Scale Carbon Management.*

As noted, at the federal government level, a key focus is the Department of Energy, which in FY 2016 administered three-quarters of Federal investment in clean energy innovation. Other agencies with significant clean energy innovation budgets include the Department of Defense (DOD), the Department of Transportation (DOT), and the Department of Agriculture (USDA); portfolios at these agencies are mission-focused, as opposed to being broadly based across all energy sectors. It is imperative that major energy innovation programs will utilize a whole-of-government approach. Carbon dioxide removal (CDR) represents a case in point. The EFI 2019 Report, *Clearing the Air*, provided a set of recommendations and detailed implementation plans for a comprehensive, 10-year, $10.7 billion research, development, and demonstration (RD&D) initiative in the U.S. to bring new pathways for technologically enhanced CDR to readiness for widespread application. The wide range of scientific challenges requires an interagency effort spanning the mission responsibilities of 12 federal departments and agencies, with DOE, the Department of Agriculture and the National Oceanic and Atmospheric Administration playing key roles (Figure 8).

Figure 8. Comprehensive Carbon Dioxide Removal RD&D Initiative



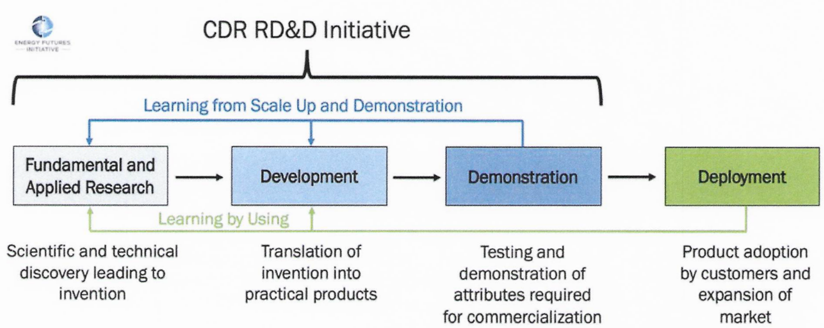
Source: EFI, 2020.

The effective planning, budgeting, and execution of the CDR RD&D initiative will require effective coordination led by the Office of Science and Technology (OSTP) and the Office of Management and Budget (OMB). This coordination effort is modeled from the highly successful U.S. Global Change Research Program. Similar interagency coordination mechanism may need to be strengthened in other areas of energy innovation such as advanced manufacturing technology.

Within the federal energy innovation establishment, the 17 DOE National Laboratories play a critical role. The National Laboratories provide world-class research facilities that are too expensive and specialized to be developed by universities or most companies acting alone, and by providing sustained attention to scientific issues with long time horizons and multidisciplinary complexity. Notably, five of the world's ten fastest supercomputers are housed in National Laboratories. The National Laboratories also play an important integration role among the participants in the energy innovation process, through various collaborative programs that help connect the early scientific discovery emphasis of research universities with the needs of industry for near-term solutions.

Second, it is essential that the innovation portfolio support the entire innovation spectrum, from use-inspired fundamental research through learning-by-doing demonstrations and pioneering commercialization. As shown in Figure 9, the innovation process is not a simple, linear process of (i.e., early-stage government research followed by private sector development, demonstration, and commercialization), but rather a complex process where the feedback loops can be as or more significant. A federal system that is focused solely on discovery and invention leaves the door open to other countries to translate the fruits of this research into new products, industries and jobs that are based offshore.

Figure 9. Focus of a CDR RD&D Initiative



The process of moving innovations into the marketplace generally follows these four stages; however, this process can be non-linear as a result of feedbacks stemming from technology scale up, demonstrations, and learning by using. Source: EFI, 2019.

It is essential that the federal investment portfolio support innovation in all areas. Additional investment is needed in fundamental research that will feed the pipeline for future innovation. Within DOE, the Office of Science has supported a broad program of fundamental research, including operation of large scientific user facilities that are used by university and private sector researchers (many of the university users are NSF supported). Over the past decade the Office of Science has developed a program of use-inspired fundamental research[5] through the establishment of Energy Frontier Research Centers (EFRCs). The design of this program was the outgrowth of a series of in-depth workshop meetings of the science community convened by DOE beginning in 2001 to identify areas of fundamental research needed to support energy technology breakthroughs. The workshops led to the 2007 Basic Energy Sciences Advisory Committee Report, *Directing Matter and Energy: Five Challenges for Science and the Imagination.*

[5] Use-inspired science has been referred to as Pasteur's Quadrant—an approach fitting to DOE and Mission Agencies. See Donald E. Stokes, Pasteur's Quadrant: Basic Science and Technological Innovation, Washington, DC, Brookings Institution Press, 1997.

It should be noted that the EFRCs were largely university based with some partnerships with the private sector and other research participants. While the focus of the EFRC program was on fundamental research, it produced significant advancements in the technology base to support subsequent commercialization. This connection is illustrated by the fact that DOE reports that EFRC research has led to more than 650 invention disclosures and 180 patents, with 100 companies having directly benefited from EFRC direct partnerships, patent licensing, and transfers of scientific findings to technology developers.

In this regard, the National Science Foundation (NSF) also can play a critical role through its established network of research university-based principal investigators and collaborative research centers. While the NSF is appropriately focused on fundamental research, and should remain so, there is an opportunity to further expand the NSF role beyond discovery science to support use-inspired fundamental research in areas of science and engineering that can accelerate technology innovation, especially in platform technologies, such as advanced computation, synthetic biology, cybersecurity, risk assessment and decision science that underpin many potential inventions of and applications to new products and services. Adding a major focus on technology development and commercialization to NSF's mission, however, would pose a major risk to the nature and culture of the agency and would need to be circumscribed with great care. The provisions in the draft House bill, *The National Science Foundation for the Future Act,* to erect a firewall between a new NSF Directorate for Science and Engineering Solutions and the existing organization are reflections of such risk.

The DOE and its system of National Laboratories play an important role in planning and implementing use-inspired fundamental research initiatives. DOE has provided leadership in platform technology areas including high performance computing, the National Quantum Initiative, artificial intelligence, cybersecurity, biotechnology and genomics. In addition, DOE has the ability to manage both open science and classified applications concurrently, a critical programmatic feature. The future role NSF in use-inspired fundamental research should be complementary to, and closely coordinated with, similar fundamental research in DOE and other federal mission departments and agencies, including joint programs, to enhance opportunities for translation of research into applied technology development, demonstration, and ultimate commercialization by the mission agencies and the private sector.

At the other end of the spectrum, government cost shared support for prototyping and demonstration projects at or near commercial scale are equally important to test the operational viability and commercial attractiveness of new technologies. The expanded list of advanced energy technology demonstration projects authorized in the Energy Act of 2020 underscores the important federal role in supporting technology scale-up and demonstration projects, and implementation of these provisions will provide significant momentum for energy innovation over the coming years.

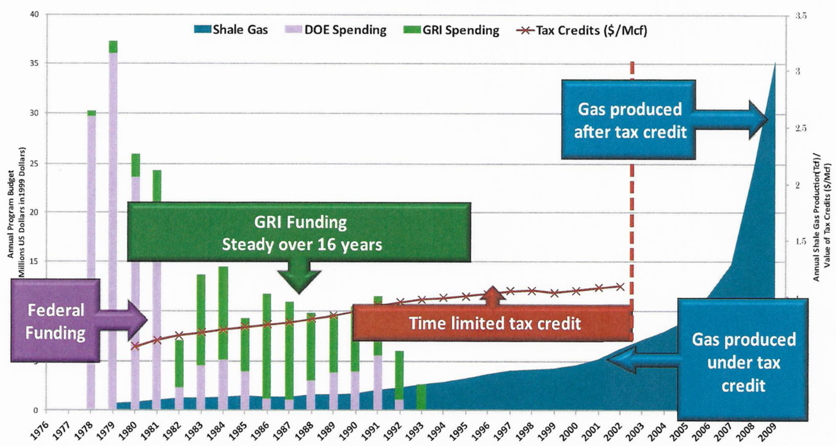
Finally, the role of the Advanced Research Projects Agency—Energy (ARPA-E) is noteworthy for its unique role in bridging between the stages of fundamental and applied research into development and scale-up. ARPA-E, established in the America COMPETES Act of 2007 pursuant to a recommendation by the National Academies of Science, Engineering and Medicine in the *Rising Above the Gathering Storm* Report, has been given more program flexibility than other DOE applied energy R&D programs to spur acceleration of innovation in cutting edge areas of energy technology. The success of ARPA-E has been widely acknowledged in various metrics on patents, follow-up investment and formation of new companies.

The ARPA-E mission and functions were favorably evaluated in the June 2017 report by the National Academies, *An Evaluation of ARPA-E*. The FY 2021 Energy and Water Development Appropriations Act raised the annual funding level to $427 million, but it is still less than half the level recommended at the time of its establishment over a decade ago. This has led to suboptimal award rates, with many good ideas left on the table. Increased funding for ARPA-E should be considered as one of the highest priorities for Congress in the new budget cycle. Consideration also should be given to broadening its programmatic reach, by allowing ARPA-E for example to increase the length and size of grant awards. The Biden Administration request for FY 2022 discretionary funding includes a total of $1 billion combined for both

ARPA-E and the proposed Advanced Research Projects Agency—Climate (ARPA-C). No additional details are yet available as to the allocation between the two entities or to the proposed portfolio for ARPA-C.

Third, the innovation portfolio needs to be closely coupled to deployment incentives. The development of the U.S. shale gas industry offers a textbook example of how strategic investments in innovation, coupled with public-private partnerships and targeted, time-limited financial incentives, can work together to successfully launch a major energy transition. As seen in the Figure 10, federal investments in technology development in drilling technology and federally funded resource assessments provided the foundation for development of shale gas (and oil) technology.

Figure 10. Federal Investment,Policies, Industry Support: US is Now the Number One Gas Producer in the World



Source: MIT Future of Natural Gas Study

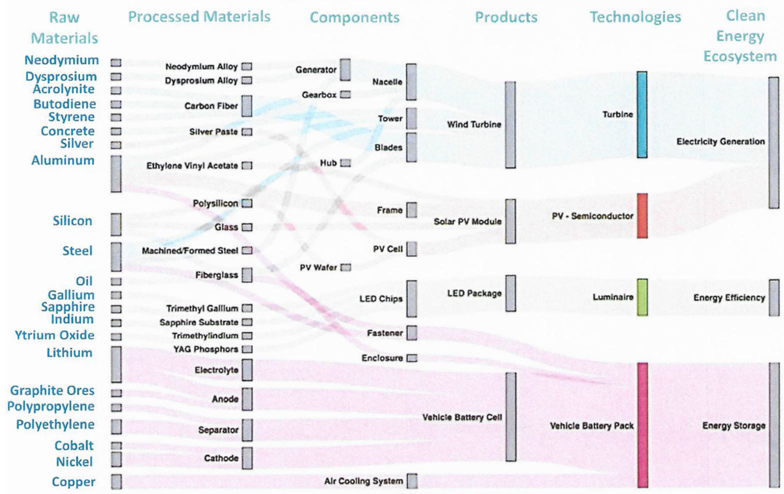
Follow-on applied R&D investment, through a public private partnership involving DOE, the Gas Research Institute (now the Gas Technology Institute) and the private sector achieved proof of concept of shale gas drilling techniques. The availability of the nonconventional gas tax credit provided an important incentive to encourage the initial deployment. The industry then matured on the basis of learning-by-doing improvements in productivity. This same model may be relevant to the development of the advanced nuclear technology and the offshore wind industries.

Fourth, energy innovation programs need to provide greater emphasis on supply chain issues. As noted earlier, advanced clean energy technologies are increasing dependent upon critical metals and minerals, as shown in Figure 11.

Meeting the increased demand for critical metals and minerals will likely require a corresponding-increase in domestic mining, albeit mining that employs environmentally sustainable practices. It will also require the development of stable, strategic international supply chains. Targeted RD&D activities can supplement these strategies. Opportunities for materials substitution and materials recycling, as well as alternative approaches for materials processing and equipment manufacturing should become a requirement for all DOE funded RD&D for clean energy technologies. Strategies for commercial deployment should take into consideration security and reliability of supply chains and develop appropriate acquisition strategie

Fifth, the implementation of energy innovation programs needs to be cognizant of regional variations

Figure 11. Sankey Diagram of Clean Energy Technology Supply Chain



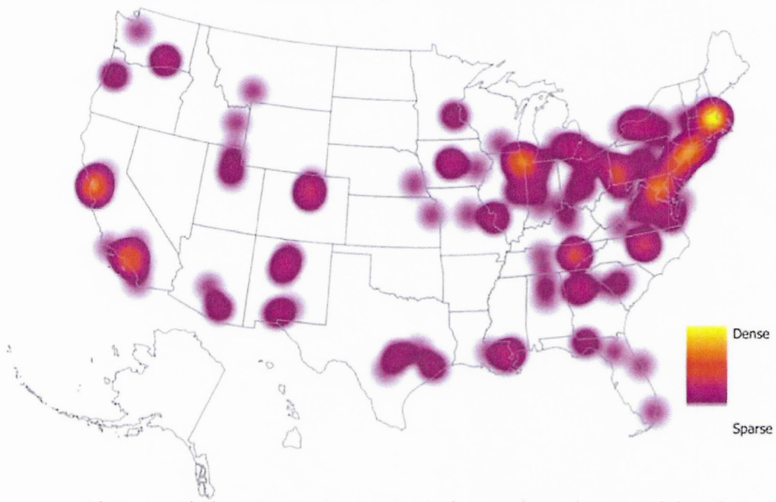
The clean energy technology supply chain is vast and complex but also includes numerous interconnections between raw materials and technologies.
Source: McCall, 2017, Clean Energy Manufacturing Analysis Center

and needs to exploit regional innovation strengths. Nurturing energy innovation ecosystems at a regional scale can be the critical catalyst for aligning the key players, policies and programs among the private sector, universities and governments. Energy resources, expertise and markets vary significantly by region of the country, and many of the issues facing the energy sector can be better managed by strategies tailored to each region's specific needs.

Analysis of national data on energy innovation reveals strong regional clustering. Combining data on the location of Department of Energy (DOE) national laboratories and Energy Innovation Hubs, the DOE-funded Energy Frontier Research Centers, the National Network for Manufacturing Innovation Centers, NASA laboratories and facilities, the top 100 research universities, and the major Federally Funded Research and Development Centers (FFRDCs) into a single heat map shows significant clustering of innovation capabilities (see Figure 12). What the heat map shows is that there is a robust system of innovation enablers in many, but not all, parts of the United States.

Federal policies and programs should be cognizant of these developments and seek to nurture further evolution. The DOE National Laboratories and other federally funded research institutes, working with universities, can play a major role in catalyzing regional energy innovation ecosystems.

Figure 12. EFI's Regional Clean Innovation Index



EFI's Regional Clean Energy Innovation Index combines locational data for energy RD&D resources across the country to analyze the potential benefits to innovation of regional clustering.

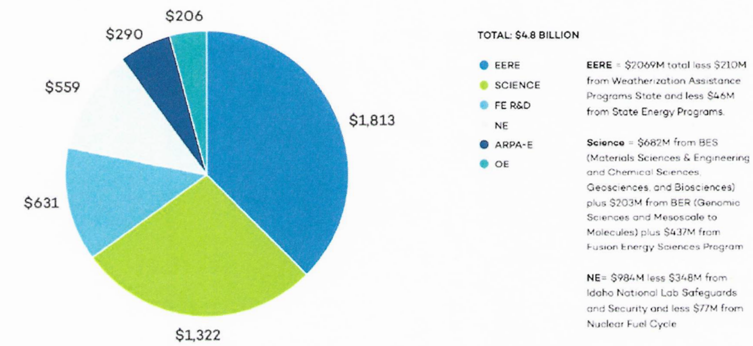
Source: Energy Futures Initiative (EFI), 2017. Compiled using data from Hersch, 2014; Manufacturing USA; National Aeronautics and Space Administration; National Science Foundation; DOE

Finally, the federal energy innovation research portfolio needs to be better planned and managed for performance. The DOE applied energy research programs are currently organized around a fuel centric framework that has its origins in the 1970s, a structure that inherently skews its programs and budgets. It tends to lead to budget allocations by fuel, resulting in gaps and budget distortions, rather than prioritization by innovation potential. The 2019 study *Advancing the Landscape of Energy Innovation*, included an analysis of the FY 2017 DOE budget comparing the budget allocations by organization with a budget allocation by application, shown in Figure 13.

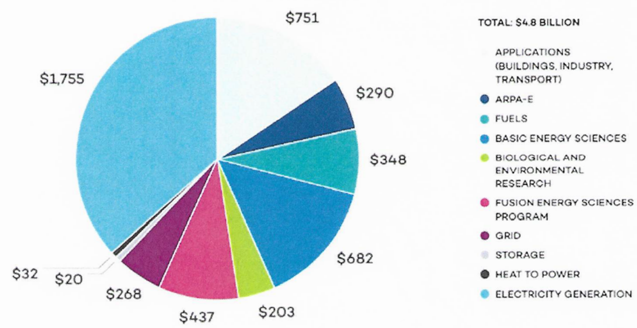
The comparison highlights the relative lack of attention to several key technology areas such as energy storage, grid modernization, heat to power, and hydrogen and other clean fuels. Emerging areas of research needs, such as carbon dioxide removal, had no clear organizational home. The DOE Quadrennial Technology Reviews of 2012 and 2016 represented steps toward better portfolio planning. These efforts should be reinvigorated. In particular, the Conference Report accompanying the Energy and Water Development Appropriations Act for 2021 underscored the need for better multi-year R&D portfolio planning, noting that "The Department is still not in compliance with its statutory requirement to submit to Congress, at the time that the President's budget is submitted, a future-years energy program that covers the fiscal year of the budget submission and the four succeeding years."

Figure 13. Comparison of DOE Budget Structures by Organization and Application

DOE Budget Structure by Organization ($millions)



DOE Budget Structure by Application ($millions)



Source: EFI, 2017. Compiled from DOE Fiscal Year 2018 Budget Documents

The current structure also lacks clear direction for supporting all stages of the innovation process from fundamental research through commercial demonstration. Demonstration projects are an essential element of the innovation process for testing new technologies at scale with full integration of components and sub-systems. The learning by doing achieved through demonstration projects is an essential two-way street, enabling any necessary fine tuning as technologies enter commercial deployment as well as providing important feedbacks to guide further research priorities. The management of DOE large-scale demonstration projects has a checkered history, leading some critics to propose the proverbial "throw out the baby with the bathwater." Adopting a more rigorous project management guidelines to demonstration projects along with stronger project management oversight, modeled after those applicable to DOE internal construction projects, will be necessary to ensure effective implementation of the new demonstration projects authorized in the Energy Act of 2020.

Conclusion

All of this points to the need for, and ability of the U.S. to sustain its preeminence in clean energy technology innovation but requires far-sighted and sustained action to better align the policies, players and programs that are the key building blocks of our national energy innovation ecosystem. It is my pleasure—once again—to appear before this Committee. I have always found that Members from both sides of the aisle are willing to work together to support U.S. energy innovation, and I would be happy to support your efforts in any way.

Madam Chair, Ranking Member Lucas, members of the Committee, I appreciate the opportunity to testify today on critical clean energy innovation needs. I look forward to your questions.

[i] https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx

The CHAIRMAN. With that, I will turn it over to Ranking Member Barrasso for his opening remarks.

STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM WYOMING

Senator BARRASSO. Well, thank you very much, Mr. Chairman. Much of what I want to say echoes the wonderful comments that you just made. Thank you for holding today's hearing. It is very, very important.

In our experience with the COVID–19 pandemic, if that experience proves anything, it proves that innovation is not a luxury, it is a necessity. It is hard to imagine managing this pandemic without innovations in human gene mapping, in advanced computing and in vaccine development. Likewise, it is hard to imagine addressing environmental challenges like climate change without further innovations in energy production, in consumption. Innovation is a source of strength and a key advantage in our geopolitical competition with China. The Department of Energy is our country's preeminent agency for driving innovation in technology. It has made significant contributions to the energy sector. It has been a leader in our critical areas of basic and applied science. The Department's research helped bring about hydraulic fracturing, the technology to extract oil and gas from dense rock formations called shale. This technology has made the United States the world's top producer of oil and natural gas. It has created millions of high-paying jobs, and it has given Americans among the lowest energy prices in the industrialized world.

The Department offered early support to Tesla, now the world's most valuable car company. The Department's national labs developed the fuel necessary for NASA's deep space missions, including missions to Mars and Pluto. The Energy Department has contributed to the discovery of a number of new elements and has helped revolutionize the fields of electronics and quantum computing. The Department's 17 national labs are America's and the world's crown jewels of science and technology innovation. Two of the world's three largest, fastest supercomputers are located at national labs. Using these computers, the Department played a significant role in helping us understand and treat COVID–19. In partnership with the National Institutes of Health, the Department of Energy played a leading role in helping us understand DNA and the structure of human genes. The Department also plays a leading role in advanced manufacturing and does critical work on cybersecurity.

With a track record like this, you wouldn't think the Department would have to worry about Congress giving its mission to another federal agency. Yet, that's exactly what is being contemplated. Majority leader Schumer wants to take up legislation that would duplicate much of the Department's mission at the National Science Foundation. Schumer's bill would give the Foundation $100 billion to create a new technology directorate. The directorate would duplicate and compete with the Department of Energy. To make matters worse, the legislation would explicitly prohibit our national laboratories from competing for this funding. Mr. Chairman, before the Schumer bill gets Floor consideration, we should be asking some basic questions, including how is this duplication of effort a responsible use of taxpayer money? How does such duplication help us compete with China? What kind of message does it send to the Department of Energy's researchers, who have devoted their lives to innovation? And what does it mean for the future of this Committee's work on science and technology?

Make no mistake, the Department of Energy can make improvements in its R&D programs, but I would like to see more investment in building research capacity at universities in rural states, including Wyoming. Radically expanding another federal agency's mission and funding to compete with the Department is not the answer.

Our competition is with China. We should stay focused on China instead of creating wasteful rivalries between federal agencies.

Thanks so much, Mr. Chairman, for holding this very important hearing, and I look forward to hearing the testimony.

The CHAIRMAN. Thank you, Senator Barrasso.

Today's witnesses include experts with direct and detailed knowledge of the Department, the national labs, and the private sector partners and their global competitors. I would like to welcome all of you to the Committee for this important discussion on the role of the Department of Energy and national labs and American energy innovation and how its research, development, demonstration, and deployment programs may be enhanced to further boost the economic competitiveness of the United States.

We will hear first from Dr. Tom Mason, the Director of Los Alamos National Laboratory and the former Director of Oak Ridge National Lab. Dr. Mason, welcome to the Committee.

Second, we are going to hear from Dr., I want to make sure I get it correct, Mr. Paul Dabbar, the CEO of Bohr Quantum, the former Under Secretary for Science of DOE. Welcome, Mr. Dabbar.

We want to also thank Ms. Sarah Ladislaw. Ladislaw, did I get it right? Good. Ms. Ladislaw is the Managing Director of the U.S. Program, RMI.

Welcome, very much, all three of you. We will start with Dr. Mason for your opening statements.

STATEMENT OF DR. THOMAS MASON, DIRECTOR, LOS ALAMOS NATIONAL LABORATORY

Dr. MASON. Mr. Chairman, members of the Committee, thank you for inviting me to testify on how our national labs——

The CHAIRMAN. Doctor, I am sorry, one thing I forgot—and finally, we have Dr. Lara Pierpoint and she is the Director of Climate at Actuate and I think she is on, she will be on web with us.

Go ahead, sir, I am sorry.

Dr. MASON. Mr. Chairman, thank you for inviting me to testify on how our national laboratories contribute to scientific innovation and the scientific tools needed to maintain our competitiveness. I've prepared some longer remarks and would request that my entire statement be entered into the record.

I've spent most of my career within the Department of Energy national laboratories, but also spent time as a faculty member at a public research university, in industry and at a European national lab and this gives me a great appreciation for the technological harnessing that only the U.S. Federal Government can foster. The Department of Energy national laboratory system has delivered scientific advances in technology solutions for the nation in such areas as nuclear power, satellite communications, medical imaging, supercomputing, advances in energy efficiency and initiation of the human genome project. The U.S. dominated for decades in these and other fields, but our competitors have not been sitting still. Today, technology innovation remains the key to economic growth and national security. While we're still a major player today, we are no longer a uniquely dominant force globally. Innovation is emerging around the world and we can no longer take our leadership for granted.

Our global competitors are investing significant funds into their scientific and national security research institutions. In fact, they're modeling those institutions off our national lab system. President Xi Jinping stated that China's success is dependent upon a national laboratory system and it's no accident that the Chinese believe that investing in basic scientific research and the creation of a national lab system that's explicitly modeled on ours, will lead to science and technology (S&T) innovation breakthroughs. While we have a multi-decade head start, much of the research infrastructure in the U.S. is aging. If we're to compete for the leadership role of the future, the U.S. must both revitalize its physical and human capital infrastructure and have a coordinated approach between the many agencies, institutions and private industry that are currently working in key emerging technology areas.

The laboratories build and maintain unique, large-scale and world-leading research tools that are utilized broadly by academic and industrial researchers. They also serve as an irreplaceable, on-the-job training ground for students, faculty and early career scientists. Universities educate and train scientists, engineers and teachers and generate new ideas by performing cutting-edge research, supported by the National Science Foundation which is the only federal agency charged with the promotion of scientific progress across all science and engineering disciplines. This research has led to transformative discoveries that have reshaped our world. The role of industry is critical to moving basic ideas and early- and mid-stage applied research to products that are ready for the marketplace. Industry drives commerce and innovation through in-house research and by harnessing scientific advances and technology developed at universities and national laboratories.

Significant integrated investments across our nation's S&T assets is needed if we are to remain competitive across the international stage because the whole of this system is greater than the sum of its parts. Universities, national laboratories and industry are all needed. Americans' innovation ecosystem is the envy of the world which is why so many of the other nations are trying to copy our model. And I would just add, it's actually the diversity of our approaches, the variation in the mission drivers in different government agencies that is really one of the signature strengths of the U.S. system.

So thank you for your attention, and I look forward to the discussion.

[The prepared statement of Dr. Mason follows:]

Testimony of
Dr. Thomas Mason
Director, Los Alamos National Laboratory

U.S. Committee on Energy and Natural Resources

"Hearing to Examine the Leading Role of the DOE and Energy Innovation in American Economic Competitiveness"

April 15, 2021

Mr. Chairman, thank you for inviting me to testify on how our national laboratories contribute to scientific innovation and the scientific tools needed to maintain our competitiveness.

I would first like to commend the many members of the Senate who recognize the critical role that innovation, driven by federal investment in research and technology development, plays in competing with other nations and ensuring US leadership in key technology areas. I have spent most of my career within the Department of Energy National Laboratories but also spent time as a faculty member at a public research university, in industry and at a European National Laboratory. This gives me a great appreciation for the technological harnessing that only our federal government can foster.

Since its founding in the Manhattan Project, the Department of Energy (DOE) national laboratory system has delivered scientific advances and technology solutions for the nation, while balancing the need for open, collaborative science with the imperatives of national security, economic and energy security, and technological superiority. The innovation from the Manhattan Project and Cold War era propelled the U.S. to be the world leader in nearly every technological area for several decades.

Innovation in this era led to such things as nuclear power, satellite communications, medical imaging, supercomputing, advances in energy efficiency, and the human genome project. The U.S. dominated for decades in these fields, but our competitors were not sitting still either. Today technology innovation remains the key to economic growth ***and*** national security.

Although our competitors are making strides to catch the U.S, our leadership is still clear in a number of areas. The US continues to lead the world in pushing the boundaries in space, thanks to both government and private investments. Landing of the Curiosity Rover on Mars and the advent of Space X's reusable rockets reaffirms that this country is a world leader in space and can form effective partnerships with private industry simultaneously. While this is a clear example of US leadership, there are other examples like semiconductor and microelectronics fabrication and packaging, computer hardware and software design, autonomous vehicle development, telecommunications, and surveillance technology where it's not so clear. In the postwar/cold war era when the National Labs grew into prominence the U.S.

had a larger economy and larger research enterprise than the rest of the world combined. In the 21st century, while we are still a major player, we are no longer a uniquely dominant force. Innovation is emerging globally and we can no longer take our leadership for granted.

While the U.S. has invested significant sums into high performance computing, China has surpassed this and may beat the U.S. to deploying an Exascale computing platform. The same is playing out in artificial intelligence and 5G networks. In the national security realm, China and Russia are more rapidly modernizing their nuclear stockpiles and have newer weapons research and validation tools that are similar and possibly more powerful than U.S. facilities. China is now the world's largest electricity producer, and is building resiliency into the modernization of its power grid, including application of AI, and potentially quantum technologies in the future.

Our global competitors are investing significant funds into their scientific and national security research institutions. In fact, they are modeling these institutions off of the U.S. national lab system. President Xi Jinping, for example, stated that the success of China's "Two Bomb, One Satellite program" is dependent upon the integration of leading scientists, academics, and leading innovation system construction. He stated, "A number of national laboratories should be established, and the existing state key laboratories should be reorganized to form a laboratory system in China." It is no accident that the Chinese believe that investing in basic scientific research and the creation of a Chinese national lab system will lead to S&T innovation breakthroughs.

The blueprint for Chinese comprehensive national laboratories is explicitly modeled on our system – imitation may be a form of flattery but it is no time for complacency. While we have a multi decade head start it means that much of the research infrastructure in the U.S. is aging. Our institutions and people have been further challenged by the current pandemic and it has been gratifying to seeing the response to this crisis. If we are to compete for the leadership role in the future, the U.S. must both revitalize its physical and human capital infrastructure and have a coordinated approach between the many agencies, institutions, and private industry that are currently working in key emerging technology areas. This U.S. innovation ecosystem is noteworthy for the complementary roles that national labs, universities, and industry play.

The DOE and its laboratories strike a delicate balance between open science and S&T in the national interest. The laboratories build and maintain unique, large-scale and world-leading research tools that are utilized broadly by university and industrial researchers like supercomputing facilities and an array of light and neutron source user facilities. They also serve as an irreplaceable on-the-job training ground for students, faculty, and early career scientists through the many different student programs supported by DOE. The alumni of these programs populate laboratory, industry, and university workforces. They also go on to create many different startups in many different technological areas.

The Labs also assemble and nurture multi-disciplinary teams of scientific experts to meet federal needs and address national priorities by attacking R&D challenges of scale and translating those advances to practice. Consortia supported by the Department are accelerating the development of modern approaches to grid management and the hydrogen economy. The ability of the labs to work together rapidly to solve problems was further evidenced most recently by the research and development efforts of the National Virtual Biotechnology Laboratory (NVBL), established in response to the COVID-19 Pandemic. The NVBL used laboratory capabilities to support rapid development of anti-viral agents and vaccines, supported many different organizations with modeling disease spread and providing real-time tools for decision making and risk assessment, aided in increasing testing throughput, and used advanced manufacturing to address supply chain bottlenecks.

Universities educate and train scientists, engineers and teachers, and generate new ideas by performing cutting-edge research. They are supported by the NSF, which is the only federal agency charged with the promotion of scientific progress across all science and engineering disciplines; the research funded through its rigorous peer review process is vital to the public interest and has led to transformative discoveries that have reshaped our world. They provide a neutral and fertile ground for scientific collaboration and integrate key issues of policy and society into research and development.

The role of industry is critical to moving basic ideas and early and mid-stage applied research to products that are ready for the marketplace. Industry delivers these technological advances to the marketplace and to society by making strategic, early investments in new technology. They hire scientific and engineering talent produced by universities and trained at national laboratories to meet their workforce needs and remain globally competitive. Industry drives commerce and innovation through in-house research and by harnessing scientific advances and technology developed at universities and national laboratories. They also utilize and many times partner with the national laboratories to take advantage of the unique research tools of the laboratories to move technologies to the marketplace.

National laboratories occupy a unique position in this ecosystem, synthesizing and applying science and engineering to problems of national interest, often working in areas where there is the potential of national or economic security ramifications to science and technology. From our founding as part of the Manhattan project we have been focused on the full breadth of the innovation pipeline. At Los Alamos we like to say we always start with the science but we don't stop there. Our responsibility starts with the fundamental nuclear, materials, and chemical sciences that underpin the stockpile through the engineering disciplines that realize those physics designs in real weapons system and even to the manufacturing of warheads that ultimately are deployed by the Navy and Air Force. That same mission driven focus on seeing our science engineering deployed extends to other areas such as energy and pandemic response.

In order to continue turning out world leading S&T, I recommend investments across this ecosystem. The need to engage the full breadth of our science ecosystem has also been highlighted in several recent reports, including those from PCAST and the Council on Competitiveness. Investment is needed in the Department of Energy and the national laboratories, in coordination and collaboration with the National Science Foundation (NSF), to advance key technology areas and to fund increased access to world-leading user facilities utilized by NSF scientists to advance scientific discovery and technology development. Providing greater resources across the innovation ecosystem is the best way to achieve the Senate's goals of bolstering our competitiveness with countries like China. Our distributed, multi-agency, multi-stakeholder approach to science and technology has served the nation well throughout its history. We bring diverse viewpoints, wide ranging capability, and individual creativity and ingenuity to science and technology in a way no other country can match.

Three illustrative areas where integrated collaboration is needed:

- In quantum computing and information systems, the National Laboratories are leading five National Quantum Information Science Research Hubs – each with diverse members that include American industry, universities, and National Laboratories – funded by the Department of Energy, thanks to bipartisan congressional support for the National Quantum Initiative and subsequent appropriations. These centers are part of a coordinated, multi-agency effort with the NSF and National Institute for Standards and Technology (NIST), and serve as an excellent example of a complementary, multi-agency approach.
- In high performance computing, the National Laboratories operate two out of the top three of the world's fastest supercomputers with more coming online later this year and early next through the Exascale Computing Initiative. And by nature of their design, these exascale systems will also represent the most powerful artificial intelligence machines in the world. In addition to the supercomputers, the National Laboratories have some of the world's leading experts in computer science and advanced mathematics, which is crucial to leveraging each new generation of bigger and better computing capabilities through advanced software development. The pipeline of these experts is fueled by complementary investments in the NSF and the researchers those investments produce. This is also a key area where DOE and the National Labs have long maintained the delicate balance between the need for open science and imperative for national security as stewards of the nation's nuclear deterrent, as evidenced, e.g., by partnerships between DOE's Office of Science and NNSA.
- In advanced energy, industrial efficiency, and materials science, the Department of Energy – across nearly its entire portfolio – is the lead agency for the nation in driving innovation through research and development efforts at National Laboratories and universities in partnership with industry. Ideas generated through NSF investment at universities are proven out at DOE user facilities and translated to realization through National Lab-University-Industry consortia. DOE plays a key role in capability development and stewardship, especially at the National Labs; and in supporting robust public-private partnerships. Similarly, NSF user facilities (including the National High Magnetic Field Facility, a partnership between Florida State University, the University of Florida, and Los Alamos National Laboratory) enable forefront science in materials, energy and life sciences.

Significant investments in our nation's S&T ecosystem are needed if we are to remain competitive on the international stage. However, these investments should be made in an integrated manner that supports all the parts of the ecosystem, because the whole of this ecosystem is greater than the sum of its parts. And the parts are interdependent – universities, national laboratories and industry are all needed, and all need each other, for the ecosystem to thrive. America's innovation ecosystem is the envy of the world, which is why so many other nations are trying to copy our model. The grand scientific challenges of the 21st Century are so large they require full mobilization of the assets in our research enterprise, well-coordinated across agencies. We need to recognize the challenge of international competition but not shy away from cooperation with partners who share our values and commitment to transparent collaboration to the mutual benefit of all parties involved. America looks to Congress and the White House to ensure that the ecosystem remains healthy and vibrant.

The CHAIRMAN. Thank you. Thank you very much, sir.

Our next presenter, we have this in order here, is going to be Mr. Paul Dabbar.

Mr. Dabbar.

STATEMENT OF HON. PAUL M. DABBAR, FORMER UNDER SECRETARY FOR SCIENCE, U.S. DEPARTMENT OF ENERGY, AND CHAIRMAN AND CEO, BOHR QUANTUM TECHNOLOGIES

Mr. DABBAR. Thank you, Chairman Manchin and Ranking Member Barrasso. Thank you again for having me before this Committee. It's an honor to discuss the role of the Department of Energy in its leadership role of research, development and deployment of technologies to advance the country. I would like to start by thanking this Committee for its leadership and historically high investment in DOE and the national lab complex. Your passage of the Energy Act of 2020, the Office of Science reauthorization and the National Quantum Initiative have made large differences in discovery and innovation. America is pushed forward by those on the frontier and my colleagues at the national lab complex are able to do that because of the leadership of this Committee.

But rather than discuss the past, I would like to comment about the future. During this session there have been proposals for further investment in the nation's R&D to support economic growth and national security. With all the proposals before the Senate, the House, and from the President, I want to add my support and the whole research community's support for additional investment into R&D. But in addition to support for the broad R&D increases, to better position ourselves globally versus the likes of communist China, I also want to advocate for DOE to have a leadership role in any final proposal passed.

As you are aware, DOE has stood up the Manhattan Project from the successor organizations and as a result, mission-driven science has been at the core of DOE since the beginning. Most of the areas targeted for further investment including artificial intelligence, high-performance computing, quantum, genomics, cybersecurity, materials and advanced energy are areas that DOE has been a leader, if not the leader. Highlights of DOE leadership include, in 2019 the U.S. became a net energy exporter for the first time since the 1950s while concurrently driving down energy costs for the American people and leading the world in emissions reductions. These dramatic accomplishments were driven by the American—by American innovation supported by DOE and the national labs, including in nuclear power, solar and enhanced oil and gas production, DOE-supported researchers won the Nobel prize for lithium-ion chemistry leading to revolutions in electric vehicles and grid-scale batteries; and DOE has the successful ARPA-E program with its recent large success of QuantumScape, a solid state battery company first funded by ARPA-E and is now worth $17 billion.

DOE has held the global leadership and high-performance computing for decades. Examples including the commissioning of the then number one and number two supercomputers at Summit and Sierra and the Exascale computing program. DOE is the largest funding agency for the National Quantum Initiative, building on decades of the national labs in high energy physics, computing and materials. DOE provides cybersecurity and cyber operations leadership as the lead agency for the power sector as well as support for national security. And DOE has had a very important role in biotechnology and genomics, including the founding of the Human Genome Initiative which led to the Human Genome Project. And Berkley Lab was an early funder of Nobel Prize winner, Dr. Jennifer Doudna, who invented gene editing and her efforts were supported by light sources at a number of the DOE national labs. DOE has significant experience in driving discovery to applications and has provided significant leadership in most of these areas that have been proposed.

DOE is also moving forward with leadership in these areas including in carbon capture, post-Exascale high-performance computing, fusion, and quantum networks. We therefore urge that any final bill include DOE leadership along with Commerce and NSF in new efforts. In addition, the ability of DOE to manage both open science and classified applications concurrently will make it very valuable. DOE has a long history of many dual-use technologies. Given high-performance computing, quantum, AI and many of the other areas proposed have significant classified aspects, DOE is best positioned to balance those areas.

And finally, I would recommend that this Committee have direct responsibility for authorizing and for oversight for the new efforts from the labs such as NETL and in areas such as nuclear power and oil and gas technologies and for you to consider this topic further within your Committee and with other members of the Senate, I would ask you to find a role for DOE in any final proposal.

[The prepared statement of Mr. Dabbar follows:]

STATEMENT BY

THE HONORABLE PAUL M. DABBAR

FORMER UNDER SECRETARY FOR SCIENCE

U.S. DEPARTMENT OF ENERGY

CHAIRMAN AND CEO, BOHR QUANTUM TECHNOLOGIES

BEFORE THE SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

ON THE ROLE OF DOE LEADERSHIP IN RESEARCH, DEVELOPMENT, DEMONSTRATION AND DEPLOYMENT

APRIL 15, 2021

Chairman Manchin, Ranking Member Barrasso, and Members of the Committee, I am honored to discuss the role of the Department of Energy's leadership role in the research, development, and deployment of technologies to advance the country.

I would like to start by thanking this Committee for its leadership on the historical high investment in DOE and National Lab complex. Your passage of the Energy Act of 2020, Office of Science re-authorization, and National Quantum Initiative, have made large differences in discovery and innovation. America is pushed forward by those on the frontier, and my colleagues at the Complex are able do that every day thanks to your leadership.

But rather than discuss the past, I would like to comment about the future. During this session there have been proposals for further investment the nation's R&D, to support economic growth and national security.

This week, all the former Under Secretaries for Science including myself wrote a letter to this committee supporting further R&D investment. With proposals before the Senate, including Leader Schumer's, proposals from the House, and the President, we wanted to add our voices in support of that.

But in addition to support for broad R&D increases, to better position ourselves globally from the likes of Communist China, we also advocated for DOE having a leadership role in any proposal passed.

As you are very aware, DOE was stood up from the Manhattan Project and successor organizations, and as a result, mission-driven science has been at the core of DOE and the Complex.

Most of the areas targeted for further investment, including Artificial Intelligence, High Performance Computing, Quantum, Genomics, Cybersecurity, Materials, and Advanced Energy, are areas that DOE has been a leader, if not the clear leader.

Highlights of DOE leadership:

- In 2019, the U.S. became a net energy exporter, for the first time since the 1950's, while concurrently driving down energy costs for the American people, and leading the world in emissions reductions. These dramatic accomplishments were driven by American innovation, supported by DOE and the National Labs, including in nuclear power, solar, and enhanced oil & gas production. DOE supported researchers won the Nobel prize for lithium-ion chemistry, leading to revolutions for electric vehicles and grid scale batteries. And DOE has the successful ARPA-E program, with its recent large success of QuantumScape, a solid state battery company first funded by ARPA-E, now worth $17 billion.
- DOE has held global leadership in High Performance Computing for decades – examples include the commissioning of the then global #1 and #2 Summit and Sierra supercomputers, and the Exascale program.
- DOE is the largest funding agency for the National Quantum Initiative, building on decades at National Labs in high energy physics, computing and materials.
- DOE provides cybersecurity and cyberoperations leadership, as the lead agency for the power sector, and well as support for national security.
- DOE has had a very important role in biotechnology and genomics, including the founding of the Human Genome Initiative, leading to the Human Genome Project. BerkeleyLab was an early funder of Nobel-prize-winning work in gene editing by Dr. Doudna, and her efforts were supported by DOE light sources.

DOE has significant experience in driving discovery-to-applications, and has provided significant leadership in most of the areas in the Endless Frontier Act.

And DOE, is already moving forward with leadership in these areas, including carbon capture, post-Exascale high performance computing, fusion, and first quantum networks.

We therefore urge that the final bill includes DOE leadership, along with Commerce and NSF, in the new efforts.

In addition, the ability of DOE to manage both open science and classified applications concurrently will be very valuable. DOE has a long history of managing many dual use technologies. Given HPC, Quantum, AI, and most others proposed have significant classified aspects, DOE is best positioned to balance those areas.

Finally, I would recommend that this committee have a direct responsibility for authorizing and oversight of new efforts from labs such as NETL, or areas such as nuclear power, or oil & gas technologies.

As you consider this topic further within your committee and with other members in the Senate, I ask you to find a role for DOE continued leadership.

The CHAIRMAN. Thank you, sir.

Next, we are going to have Ms. Ladislaw.

STATEMENT OF SARAH LADISLAW, MANAGING DIRECTOR, U.S. PROGRAM, RMI

Ms. LADISLAW. Chairman Manchin, Ranking Member Barrasso, members of the Committee, thank you for having me here today. The last time I testified before this Committee was in April 2019. In that testimony I stated my view that the United States is one of the most energy-advantaged nations on the planet. Not only do we have every conceivable tool at our disposal to chart a viable pathway to a net zero-emissions, resilient energy system at home, but we also have the unparalleled ability to provide global leadership in the strategies and technologies that can bring sustainable and affordable energy supplies to the world. We just have to decide to do it. I still believe that this is true today and I'd like to revisit the issue of energy innovation and U.S. competitiveness to explain what more needs to be done and the important role that the U.S. Department of Energy, along with other agencies, can play. I'd like to make three key points.

First, the clean energy opportunity is simply enormous and represents one of the most promising and important markets of today and of the future. BloombergNEF estimates companies and consumers spent over $500 billion on the energy transition in 2020, up nine percent from 2019. According to the IEA, under its sustainable development scenario, investment in low-carbon energy resources could reach $2.6 trillion per year on average between 2026 and 2030. And while over 70 percent of that investment is needed to meet that scenario comes from the private sector, government investment, policy and regulation play a critical role in mobilizing the financing and technology and deployment of those technologies.

Second, clean energy competition is, in fact, heating up, but its early days. Concern over the decline in U.S. competitiveness in the field of innovation is not a new theme, but it's increasingly focused on the U.S. position relative to China. Indeed, China has established a commanding lead in certain energy technologies like solar PV, wind, nuclear and electric vehicles. My written testimony discusses this in a great more detail. More and more countries though are introducing plans that include funding proposals, policies and targets to help cultivate national competitiveness in the future of clean energy technologies like the UK "Ten Point Plan for a Green Industrial Revolution," Korea's $144 billion "Green New Deal" and the European green new deal. According to the International Energy Agency fully half of the technologies needed to reach net zero emissions goals by 2050 need further development to either improve performance, reduce costs or both. Compared to the more established markets of wind and solar and EVs today, the relative competitiveness of each country around the world is less developed and the positioning to compete in these technologies of the future is getting underway in earnest right now.

Third, the U.S. needs innovation and coordination. The government needs an overwhelming innovation strategy, excuse me, an overarching innovation strategy to address the shortcomings and needs of the economy as a whole, across technologies and throughout the federal lab and university complexes and programs, but the U.S. energy innovation and competitiveness strategy needs a more dedicated direction and focus. First, we need to define the areas where the U.S. wants to compete. Second, we need to increase our R&D relative to the size of the energy market. Third, R&D is not enough. We need to think about the markets that we're creating to take up these technologies. And finally, the United States needs to focus on becoming a manufacturer to ensure that the technologies of the future are produced here at home in the United States.

All of this points to the need for greater planning and coordination across government agencies to execute a much more deliberate strategy that mobilizes the innovation forces of the private sector as well. To that end, it seems important to establish a lead agency to coordinate the kind of multidimensional planning and more assertive clean energy industrial strategy or clean energy innovation strategy requires. DOE should be a major player in such a strategy because it is responsible for or involved in the majority of energy-related R&D funding, manages the ongoing relationship with the national laboratory system, is the home of innovative programs and is also the only agency with deep expertise in energy policy, technology, market and geopolitical factors that are essential for meeting this challenge.

A good first step would be to have DOE undertake a Clean Energy Competitiveness Review to identify areas where the U.S. can best compete in developing and deploying clean energy technologies of the future, taking into consideration the national security issues unearthed by the supply chain resilience review underway and also prioritizing areas where there's a need to reduce dependence on certain technologies or materials or build domestic capacity to manufacture certain technologies or components. Finally, this review can and should include recommendations on the combination of investments, partnerships, incentives, both demand and supply, policies, standards and other measures that are necessary to reach the competitive potential of certain technologies.

Clean energy innovation is a very important part of U.S. competitiveness. The market for clean energy technologies has grown and is only going to get larger and as countries adopt more and more ambitious climate policies, it will continue to grow. China's approach to clean energy technology development, while far from perfect, delivered some important success for Chinese economic competitiveness and other countries are starting to advance similar models of clean industrial strategy to advance more ambitious climate policy in some instances and capture economic potential in others. The United States can do well with this burgeoning clean energy competition if it chooses to focus its efforts.

Thank you, and I look forward to the discussion.

[The prepared statement of Ms. Ladislaw follows:]

STATEMENT BEFORE SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

"Hearing to Examine the Role of the DOE and Energy Innovation in American Economic Competitiveness"

A Testimony by:

Sarah Ladislaw
Managing Director, U.S. Program, RMI

April 15, 2021

Chairman Manchin, Ranking Member Barrasso, Members of the Committee, thank you for the opportunity to appear before you today to discuss the role of the U.S. Department of Energy (DOE) and energy innovation in American economic competitiveness. My name is Sarah Ladislaw, and I serve as managing director of the U.S. Program at RMI. Founded in 1982, RMI is an independent, nonpartisan, charitable nonprofit dedicated to transforming global energy use to create a clean, prosperous, and secure low-carbon future.

Before joining RMI this week, I served as senior vice president and director of the Energy Security and Climate Change Program at the Center for Strategic and International Studies, where I worked for the last twelve years. Before that, I worked at the U.S. Department of Energy in the Office of Policy and International Affairs. My testimony today will reflect my personal views based on my experience and past research. In particular, my testimony today will focus on several recent studies published during my time at CSIS.

The last time I testified before this Committee was in April 2019, at a hearing titled "Examining Opportunities for Energy Innovation and Other Potential Solutions to Help Address Global Climate Change." In that testimony, I stated my view that the "United States is one of the most energy-advantaged nations on the planet. Not only do we have every conceivable tool at our disposal to chart a viable pathway to a net zero-emissions, resilient energy system at home, but we also have the unparalleled ability to provide global leadership in the strategies and technologies that can bring sustainable and affordable energy supplies to the growing and developing populations of the world. We just have to decide to do it."[1] I still believe this is true today.

My testimony focused on many different issues, including the need to harness energy as a source of economic opportunity; to calibrate our efforts at home with globally resonant challenges like energy poverty alleviation, climate change, and energy security; and to focus on the critical role of energy innovation in American economic competitiveness. On this final issue, the topic of today's hearing, I want to congratulate the Committee for subsequently passing the Energy Act of 2020. During a time of political transition and under the societal strain imposed by the pandemic,

[1] Statement by Sarah Ladislaw before Senate Energy and Natural Resources Committee, "Examining Opportunities for Energy Innovation and Other Potential Solutions to Help Address Global Climate Change" April 11, 2019, https://www.energy.senate.gov/services/files/CD93296C-48FB-462C-BBE2-C64AB5307AA4

it is no small feat to pass the first broad and bipartisan energy legislation in over a decade. Focused on innovation, the Energy Act made essential contributions to research, development, and demonstration of energy storage, advanced nuclear, carbon capture, utilization, and storage, carbon removal, renewable energy, critical minerals and materials, industrial technologies, grid modernization, and other essential technologies.

Today, I'd like to revisit the issue of energy innovation and U.S. competitiveness to explain what more needs to be done and the important role that the U.S. Department of Energy, along with other agencies, can play.

The Growing Clean Energy Opportunity[2]

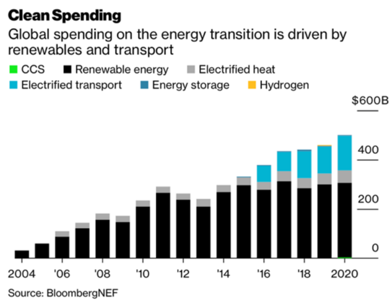
Over the last two decades, clean energy technologies like solar photovoltaics (PV), wind turbines, and lithium-ion batteries have gone from relatively expensive technologies produced and deployed by a small number of countries to cost-competitive technologies produced and deployed all over the world. Due to these cost declines, improved performance, and greater public and private sector support for renewable energy, the market for clean energy technology is positioned to grow even faster over the next couple of decades.

According to the clean energy research firm, BloombergNEF, in the United States alone, solar and wind installed capacity is forecast to rise from 180 gigawatts (GW) today to 1,329 GW by 2050 (under the Economic Transition Scenario in BloombergNEF's New Energy Outlook). Combined, solar and wind are likely to make up 56 percent of 2050 U.S. installed power generation capacity, up from approximately 14 percent today.

Similarly, BloombergNEF expects electric vehicles (EVs) will be cost-competitive with conventional internal-combustion engine vehicles by the middle of this decade. Once this important crossover point arrives, EV sales will accelerate, and by 2040, pure battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will account for the majority of new cars sold and 42 percent of the cars on roads in the United States. Over the next decade, this will represent a potential $67 billion market for battery sales in passenger EVs in the United States. Even today, in the presence of the global pandemic, clean energy investment has fared well. BloombergNEF estimates that companies and consumers spent over $500 billion on the energy transition in 2020, up 9 percent from 2019.[3]

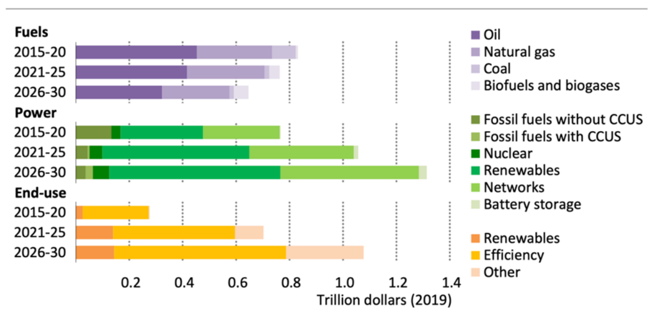
[2] Portions of this section are adapted from Sarah Ladislaw, Ethan Zindler, Nikos Tsafos, Logan Goldie-Scot, Lachlan Carey, Pol Lezcano, Jane Nakano, and Jenny Chase, "Industrial Policy, Trade, and Clean Energy Supply Chains," February 2021. A report by the CSIS Energy Security and Climate Change Program and BloombergNEF. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210224_Ladislaw_Industrial_Policy.pdf?DRja.V6axwyBE_PV6Chmdi5k2VqOq33n

[3] Josh Saul and Will Mathis, "Spending on Global Energy Transition Hits Record $500 Billion," *Bloomberg*, January 19, 2021, https://www.bloomberg.com/news/articles/2021-01-19/spending-on-global-energy-transition-hits-record-500-billion?sref=Tj5BOuJ2.



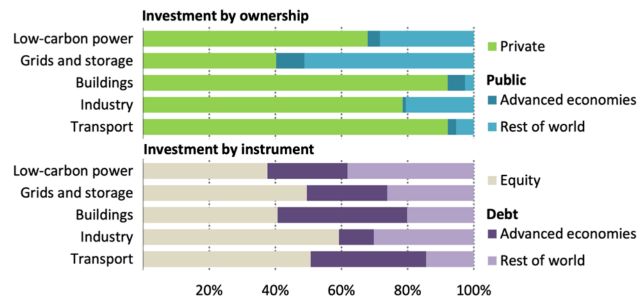
Policy plays a critical role in determining the pace and scale of growth in this market. According to the IEA, under its sustainable development scenario, investment into the energy system might reach $3.2 trillion a year, of which $2.6 trillion will be directed to low-carbon energy sources, a nearly threefold increase relative to investment from 2015 to 2019 (see figure 3.17 below).[4] While over 70 percent of the investment needed to meet this scenario comes from the private sector, government investment, policy, and regulation play a critical role in mobilizing the financing and technology deployment.[5]

Figure 3.17 ▷ Average annual energy investment in the Sustainable Development Scenario



[4] International Energy Agency, World Energy Outlook 2020, October 2020, https://www.iea.org/reports/world-energy-outlook-2020. Calculations based on Annex A Tables for Scenario Projections.
[5] International Energy Agency, World Energy Outlook 2020, October 2020, https://www.iea.org/reports/world-energy-outlook-2020, p.117.

Figure 3.18 ▷ **Clean energy-related investment in the Sustainable Development Scenario, 2025-2030**



Source: International Energy Agency (2020), World Energy Outlook 2020. IEA, Paris.

The clean energy and climate-smart technology market opportunity is not just in developed countries, either. According to an International Finance Corporation analysis, the climate change commitments submitted under the Paris Agreement and underlying policies of 21 emerging market economies, representing 48 percent of global emissions, have created a 23 trillion-dollar market opportunity between now and 2030.[6]

All of this is just based on the commitments to the Paris Agreement thus far. According to the United Nations Environment Program, by the end of last year, 126 countries had committed to, announced, or were considering targets to reach net-zero greenhouse gas emissions by 2050 (or 2060 in China's case). If enacted, these commitments would cover 51 percent of global emissions. Should the United States join, as suggested by the Biden administration, the share would be 63 percent of global emissions.[7] The investment needs and market for clean energy technologies implied by these policies would be enormous.

This type of expenditure can have real advantages too. For example, according to another recent IEA analysis, India would need to spend an additional $1.4 trillion, over and above what is projected for their stated policy goals, in clean energy capital expenditures between now and 2040 to align better its current path with what is required for a net-zero trajectory and more positive sustainable development outcomes.[8] Coincidently, $1.4 trillion is also the number of funds saved by avoided oil imports under this same scenario, showing that spending today can help with the climate challenge, local air pollution, and energy security concerns.

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[6] "Climate Investment Opportunities in Emerging Markets: An IFC Analysis," International Finance Corporation, The World Bank, https://www.ifc.org/wps/wcm/connect/59260145-ec2e-40de-97e6-3aa78b82b3c9/3503-IFC-Climate_Investment_Opportunity-Report-Dec-FINAL.pdf?MOD=AJPERES&CVID=lBLd6Xq
[7] United Nations Environment Programme, "Emissions Gap Report 2020," December 9, 2020, https://www.unep.org/emissions-gap-report-2020.
[8] "India Energy Outlook 2021," World Energy Outlook Special Report, IEA, Paris. https://www.iea.org/reports/india-energy-outlook-2021

Clean Energy Competition

Concern over the decline in U.S. competitiveness in the field of innovation is not a new theme and was the impetus for seminal reports as the National Academy of Sciences report "Rising Above the Gathering Storm," which sought to bring a high-level, strategic focus on the state of American science and technology competitiveness. As of late, however, policymaker concerns have centered on U.S. competitiveness relative to China. According to a 2018 report from the Council on Competitiveness, "China's investment in R&D has more than doubled since 2010, reaching $451 billion in 2016, second only to the U.S. investment, and set to outpace the United States by the end of this decade. China has overtaken the United States in science and engineering publications. China has an 18.6 percent world share, while the United States has a 17.8 percent share. China has posted double-digit growth rates in international patent filings in every year since 2003, and now lags only the United States in patents filed."[9]

This concern has led to a debate over the relative merits of the U.S. and Chinese innovation approaches. Early in 2017, Senator Marco Rubio published a report on U.S. competitiveness relative to China called *Made in China 2025 and the Future of American Industry* (after China's strategic planning document). In the report, the senator outlines several areas where the Chinese have laid out a strategy to be the world leader in specific technologies. These include nuclear power, renewable electricity, battery technologies, and electric vehicles in the energy sector.[10]

Indeed, China has established a commanding lead in certain clean energy technologies like solar PV, wind, and electric vehicles. According to a recent report published by CSIS and BloombergNEF, China currently has a strong presence throughout the value chain for each of these technologies.[11]

- For lithium-ion batteries, China is the largest lithium refiner, accounting for 61 percent of total capacity. China accounts for a similarly high share of cobalt refining capacity, at 72 percent, with the balance being mainly in Europe. China holds the largest market share among the world's top three-component manufacturing (China, Japan, and Korea): 52 percent for cathodes, which is the most critical component and can account for half the cost of a manufactured cell, 78 percent for anodes, 66 percent for separators, and 62 percent for electrolytes. Around 78 percent of the world's cell manufacturing capacity is located in China, with some modest capacity in Europe and the United States. Looking

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[9] National Academies of Science, Committee on Prospering in the Global Economy of the 21st Century, "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," 2007, Page 3. https://www.nap.edu/read/11463/chapter/2

[10] "Made in China 2025 and the Future of American Industry," U.S. Senate Committee on Small Business and Entrepreneurship, https://www.rubio.senate.gov/public/_cache/files/0acec42a-d4a8-43bd-8608-a3482371f494/262B39A37119D9DCFE023B907F54BF03.02.12.19-final-sbc-project-mic-2025-report.pdf

[11] Language in the following bullets taken from Portions of this section is adapted from Sarah Ladislaw, Ethan Zindler, Nikos Tsafos, Logan Goldie-Scot, Lachlan Carey, Pol Lezcano, Jane Nakano, and Jenny Chase, "Industrial Policy, Trade, and Clean Energy Supply Chains," February 2021. A report by the CSIS Energy Security and Climate Change Program and BloombergNEF. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210224_Ladislaw_Industrial_Policy.pdf?DRja.V6axwyBE_PV6Chmdi5k2VqOq33n

ahead, even if every announced U.S. project went ahead, the United States would still only have about one-tenth of China's cell manufacturing capacity by 2025.

- For solar PV manufacturing, the Chinese presence in the polysilicon market has grown over time. Since 2017, 91 percent of the new polysilicon processing capacity in the world has been built in China, and by 2019, two-thirds of the world's polysilicon manufacturing capacity was owned by Chinese firms (regardless of factory location). More than 90 percent of the world's wafer manufacturing capacity is in China, and having control over this part of the value chain has been essential to the country's dominance of the PV supply chain. Chinese companies also own about 72 percent of the world's module manufacturing capacity (regardless of factory location), a share that has stayed the same since 2016.

- For wind turbines, China's presence is still large but not quite as dominant. Of the 39 countries that make utility-scale wind equipment, only China, India, Spain, Germany, and the United States can produce all six major components: nacelles, blades, towers, generators, gearboxes, and bearings. China accounts for 58 percent of the nacelle market by plant location and 42 percent of the market based on company ownership. Other major producing countries are the United States, India, Germany, and Denmark. (In 2019, 59 percent of the world's plants were in China (by count, not capacity). For wind towers, almost half the world's manufacturing plants are in China, with Spain a distant second. Turbine manufacturing is more dispersed: almost 40 percent of the plants are located in China, but outside of China, the market is dominated largely by European manufacturers. The gearbox market is far more global since gearboxes are comparably easy to ship; roughly half of the world's plants are in China.

- Finally, for E.V.s, China is by far the largest single-country market, has a dominant presence in every component of the upstream supply chain for battery technologies, and is a growing force in the E.V. and battery innovation race. China's E.V. plan began with the rollout of conventional hybrids and more efficient gasoline vehicles, but by 2015 the focus shifted to the mass rollout of E.V.s. Unlike Western leaders in E.V. sales like Norway, China focused on expanding local manufacturing capacity in every phase of E.V. production, rather than overall sales numbers. Today, China is the largest E.V. market globally, and there has been no single policy responsible for its significant E.V. sales and battery manufacturing capacity. However, even as it dominates the upstream E.V. supply chain, China's automotive industry has yet to become internationally competitive, with few, if any, recognizable brands in global markets. This may well change as its indigenous R&D efforts bear fruit, manufacturers benefit from further economies of scale, and global consumers become more comfortable with E.V. technology.

Over the last two decades, these technologies have got from pre-competitive, niche market technologies, to mainstream, cost-competitive energy resources. In many ways, China benefitted from the prevailing attitude about clean energy technology development over the last two decades: trade in clean energy technologies could help grow the market, deploy more technology, and reduce costs. Which it did quite successfully, particularly for solar PV. But

China also deliberately cultivated a strategy to develop these technologies using multiple policy, regulatory, and investment tools on both the supply and demand side of each of these markets.

Like Europe, the United States, and Japan, China initially grew the market for solar PV, wind, and EVs through demand-side subsidies like feed-in-tariffs and renewable portfolio standards etc. China also provided almost unlimited amounts of credit and the balance sheets of major state-owned enterprises to help establish solar and wind equipment manufacturers. China's policy efforts focused both on the domestic market and export opportunities in places like Western Europe, Japan, and the United States. China's approach was so successful that in the early 2010s, the boom in Chinese manufacturing of solar and wind equipment was well underway, and Chinese exports of solar PV began to saturate a global market causing PV prices to plummet. Few manufacturers and policymakers in the West immediately recognized the threats posed by China and were thus surprised when Chinese-made PV equipment flooded across borders.[12]

China's approach to clean energy-oriented industrial policy (picking sectors, providing demand and supply-incentives, and supporting with consistent strategy) is being replicated, to an extent, by several other countries (for a more in-depth look at China's EV development strategy, see Appendix A). For example, the U.K. has launched a *Ten Point Plan for a Green Industrial Revolution*, prioritizing the development of offshore wind, low-carbon hydrogen, advanced nuclear power, zero-emissions vehicles, jet zero, and green ships.[13] Or most recently, Korea's announced "Green New Deal," which plans to spend $144 billion on renewable energy, green infrastructure, and a greener industrial sector.[14] Finally, the European Green Deal which has a series of policy, plans, investments, and mechanisms, including "A new Circular Economy Action Plan for a Cleaner and More Competitive Europe."[15] Each of these plans includes funding proposals, policies, and targets to help cultivate national competitiveness in the future of clean energy technologies. According to the International Energy Agency, fully half of the technologies need to reach net-zero emissions goals by 2050 need further development to either improve performance, reduce costs or both. A great deal that can and should be done to deploy existing, cost-competitive technologies like solar PV, wind, and EVs at a faster rate while also improving on these technologies through dedicated research and development efforts to improve future performance of these technologies. But new and improved technologies are also necessary to reduce emissions in hard-to-abate sectors and to maintain the competitive technological edge in certain industries and sectors. Compared to the more established markets of wind, solar, and

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[12] Sarah Ladislaw, Ethan Zindler, Nikos Tsafos, Logan Goldie-Scot, Lachlan Carey, Pol Lezcano, Jane Nakano, and Jenny Chase, "Industrial Policy, Trade, and Clean Energy Supply Chains," February 2021. A report by the CSIS Energy Security and Climate Change Program and BloombergNEF. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210224_Ladislaw_Industrial_Policy.pdf?DRja.V6axwyBE_PV6Chmdi5k2VqOq33n

[13] Ten Point Plan for a Green Industrial Revolution, November 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf

[14] "South Korea's Green New Deal in the Year of Transition" February 2021, UNDP. https://www.undp.org/content/undp/en/home/blog/2021/south-korea-s-green-new-deal-in-the-year-of-transition.html

[15] European Commission website for resources and document on the Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#documents

E.V.s, the relative competitiveness of each country is less developed, and the positioning to compete in these technologies of the future is getting underway.

Innovation and Coordination

The government needs an overarching innovation strategy to address the shortcomings and needs of the economy as a whole, across technologies, and throughout the federal, lab, and university complexes and programs. But the U.S. energy innovation and competitiveness strategy needs a more dedicated direction and focus. In a July 2020 report, *Race to the Top: The Case for a New U.S. International Energy Policy*, my co-author, Nikos Tsafos, and I recommended several strategies to boost American competitiveness in the clean energy race:[16]

First, define the areas where the wants to compete. Wanting to be number one irrespective of the area makes no sense. The United States continuously defines sectors that are strategic, for example, in screening foreign investment, in channeling innovation resources, in supporting exports, in setting standards, in providing subsidies, and so on. In practice, the United States has a list of priorities that are relatively shared by both political parties, but it is scary to say out loud that such a list exists or to argue that once the list is made, it should dedicate some resources to that list. That is no way to nurture a healthy and competitive economy.

Second, the amount of money that the country spends on R&D is paltry relative to the size of the energy market (even ignoring the costs associated with pollution or climate change), and it is too dispersed. Different sources give different figures, but R&D spending on energy is probably around 0.25 percent of total spending for energy goods and services. In health care, the relative ratio is closer to 1 percent, and in national defense, it is near 8.5 percent. More importantly, this budget is distributed across numerous different agencies and in pursuit of numerous different breakthroughs. The United States needs not only more resources but more targeted areas where it hopes for major innovations. The country can afford to make some big bets in the future of energy, even when and if those bets do not always pan out.

Third, R&D is not enough. The United States needs to think about the markets in which these innovations will be deployed. There is a lot of emphasis on making sure that technologies developed in a lab make it to the market, and those efforts are important. But the biggest obstacle to energy innovation is that markets favor incumbent technologies. The United States spends money to make discoveries but then prevents these discoveries from spreading due to policies that privilege existing energy resources and technologies over new ones. Of course, the United States has tools to rectify such disparities, such as tax incentives, mandates and regulations, and direct support of state institutions—depending on how much change it wants to engender. But the United States hesitates to use these well-established tools, thus undermining whatever successes it has in the lab.

Finally, the United States needs to focus on manufacturing. This is not because of an anachronistic or romantic obsession with making things. It is based, first and foremost, on the

[16] Sarah Ladislaw and Nikos Tsafos, "*Race to the Top: The Case for a New U.S. International Energy Policy*," July 2020, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/200706_SRF_RacetotheTop_WEB_v2%20FINAL.pdf

recognition that manufacturing jobs are good jobs, with backward linkages that provide a foundation for economic prosperity. There is a security dimension, too, as the country has learned painfully during Covid-19. This is not an argument about protectionism or autarky, but the idea that it does not matter at all where a good is produced is silly. Supply chains will continue to be global, but one can still think about whether those supply chains expose the country to vulnerabilities and whether those supply chains provide as much economic opportunity as they could. A simpler emphasis on manufacturing would ensure that as the world transitions to newer energy sources, many of the widgets of the future are made in the United States and that the country retains the capability to produce resources on which it depends.

All of this points to the need for greater planning and coordination across government agencies to execute a much more deliberate strategy. This should likely happen at two levels. First, there is a role for science and technology organizations like the Office of Science and Technology Policy and the National Science Foundation to think about the bedrock conditions of our science and technology competitiveness across a wide range of industries, sectors, and applications. Thinking more broadly about the health of the U.S. innovation ecosystem is an important part of the equation.

Second, it seems important to establish a lead agency to coordinate the kind of multi-dimensional planning that a more assertive clean energy industrial strategy (or clean energy innovation strategy) requires. DOE is the obvious choice for the lead agency in such a strategy because it is responsible for or involved in the majority of energy-related R&D funding and manages the ongoing relationships with the national laboratory system. It is the home of innovative programs like ARPA-E, X-prize competitions, its technology transfer and commercialization functions. It is also the only agency with deep expertise in energy policy, technology, market, and geopolitical factors. Finally, through its existing work, it has the necessary connections with other agencies and offices, private sector entities, and state and local officials.

A good first step would be to have DOE undertake a Clean Energy Competitiveness Review to identify areas where the U.S. can best compete in developing and deploying clean energy technologies of the future. This report could take into consideration the national security consideration unearthed by the supply chain resilience review underway and also prioritize areas where there is a need to reduce dependence on certain technologies or materials or build domestic capacity to manufacture certain technologies or components. Finally, this review could include recommendations on the combinations of investment, partnerships, incentives (both demand and supply side), policies, standards, and other measures that are necessary to reach the competitive potential of certain technologies.

Clean energy innovation is a very important part of U.S. competitiveness. The market for clean energy technologies has grown and will only get larger as countries adopt more and more ambitious climate policies. China's approach to clean energy technology development, while not perfect, delivered some important success for Chinese economic competitiveness. Other countries are starting to advance similar models of clean industrial strategy to advance more ambitious climate policy in some instances and to capture economic potential in others. The United States can do well in this burgeoning clean energy competition if it chooses to focus its efforts.

Appendix A: "Case Study in Industrial Policy: Batteries and Electric Vehicles in China" from CSIS/BloombergNEF report *Industrial Policy, Trade, and Clean Energy Supply Chains*[17]

In 2012, China published its Energy-Efficient and New-Energy Vehicles Industrial Plan, the central government's latest announcement of its intention to develop a domestic EV and battery industries. Lagging behind in internal combustion engine vehicle technologies, the hope was to better position China for the era of EVs and make the most of its comparative advantages in low-cost manufacturing. Less than a decade later, China is by far the largest single-country market, has a dominant presence in every component of the upstream supply chain for battery technologies, and is a growing force in the EV and battery innovation race. China's EV plan included all the classic features of industrial policy: demand and supply incentives, public procurement, clear targets, R&D funding, and government guarantees. It began with the rollout of conventional hybrids and more efficient gasoline vehicles, but by 2015 the focus shifted to the mass rollout of E.V.s. Unlike Western leaders in EV sales like Norway, China focused on expanding local manufacturing capacity in every phase of EV production, rather than overall sales numbers. Today, China is the largest EV market in the world, and there has been no single policy responsible for its significant EV sales and battery manufacturing capacity. However, even as it dominates the upstream EV supply chain, China's automotive industry is yet to be internationally competitive, with few, if any, recognizable brands in global markets. This may well change as its indigenous R&D efforts bear fruit, manufacturers benefit from further economies of scale, and global consumers become more comfortable with EV technology.

Program Design, Implementation, and Impact

In 2011, only 40,000 EVs were sold globally, and the industry was almost exclusively found in the United States, Japan, and Europe. Just 1,000 EVs were sold in China that year. While China was not a leading EV producer in 2011, it did have a foothold in the consumer battery industry, which served as a foundation for leading E.V. and stationary storage battery manufacturers. After several failed attempts, the Chinese government adopted a new approach in April 2012 with the publication of its Energy-Efficient and New-Energy Vehicles Industrial Plan 2012–2020. The nine-year plan set a more sensible pace than previous efforts. Its near-term focus was the rollout of conventional hybrids and more efficient gasoline vehicles while research and development work continued on EVs. Beyond 2015, the focus shifted to the mass rollout of EVs.

The plan had several components and targets. First, it aimed to increase research and development in key EV and energy-efficient vehicle technologies. This was perhaps the most important development area for the Chinese EV industry. It envisaged a ramp-up in public R&D funding delivered through national research labs, universities, and companies throughout the supply chain. A key developmental target was cost and the battery life cycle. Second, the plan sought to improve industry planning. To avoid overcapacity issues seen in the PV industry and in the early EV battery market, the government aimed to develop two to three leading companies in

[17] Sarah Ladislaw, Ethan Zindler, Nikos Tsafos, Logan Goldie-Scot, Lachlan Carey, Pol Lezcano, Jane Nakano, and Jenny Chase, "Industrial Policy, Trade, and Clean Energy Supply Chains," February 2021. A report by the CSIS Energy Security and Climate Change Program and BloombergNEF. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210224_Ladislaw_Industrial_Policy.pdf?DRja.V6axwyBE_PV6Chmdi5k2VqOq33n

each stage of the value chain with primary attention paid to batteries, battery materials, motors, and transmissions.

Third, the plan sought to accelerate vehicle demonstration and rollout. The government would more closely monitor the 25 demonstration cities in its "Ten Cities, Thousand Vehicles" plan to ensure public purchases of EVs actually occurred. It would also use average corporate fuel consumption targets to encourage uptake. Fourth, it called for another plan to be designed specifically for charging infrastructure to address questions of technology choice, standards, regulation, and business models. Lack of clarity on these points had stymied consumer uptake of EVs in the country. And fifth, the plan called for investment in the recycling and reuse of electric vehicle batteries. The government committed to drafting regulations on how to recycle and which companies would be responsible for doing the recycling.

The overall strategy had three target areas. First, it was to lower battery costs and improve performance. Battery modules should cost less than CNY 2000/kWh ($314/kWh) and have a life of more than 2000 cycles or ten calendar years by 2015 and should cost less than CNY 1500/kWh ($235/ kWh) by 2020. This was later updated with a target of doubling average battery pack energy density from 2016 levels by 2020 and lowering battery pack prices to $150/kWh by 2020. Second, it aimed to boost vehicle sales. By 2015, cumulative sales of BEVs and PHEVs should reach 0.5m; by 2020, cumulative sales should reach five million, and annual production capacity should reach two million. The plan was updated in 2017 to a seven million target by 2025, and the latest plan aims for BEVs to make up the majority of sales by 2035. And third, the strategy sought to improve average fuel efficiency. Passenger vehicles manufactured in 2015 would have an average fuel efficiency of at most 6.9 liters per 100km, with energy-efficient passenger vehicles reaching an average fuel efficiency of at most 5.0 liters per 100km; by 2020, these targets ratcheted to 5.0 liters per 100km for passenger vehicles and 4.5 liters per 100km for energy-efficient ones.

The Chinese government used a combination of demand and supply-side policies to further its high-level goals. Local governments also provided additional but narrower support. Direct purchase subsidies for EVs were key to boosting sales. The specific criteria have been amended a number of times over the last few years as costs of the program ballooned, but the principle has remained consistent, using incentives for both production and consumer adoption. Of the $60 billion the Chinese government is estimated to have spent on the EV industry between 2009 and 2017, around 60 percent or $37 billion was in consumer subsidies. There were fewer demand-side policies to support the battery industry in China, but the EV subsidy scheme boosted demand for batteries which in turn benefitted local companies. The push to improve energy density and battery performance also forced Chinese battery manufacturers to focus on technology development.

On the supply side, China introduced a New Energy Vehicle (NEV) credit program in 2012. Similar to California's Zero Emissions Vehicle (ZEV) mandate, China's system forces automakers to sell an escalating percentage of EVs each year. As with the direct subsidy program, the policy differentiated between performance characteristics of different technologies. There are also three multipliers—range, battery energy density, and vehicle efficiency—that are applied to the baseline NEV credits. The Chinese government also introduced foreign investment restrictions to benefit local automakers and battery suppliers. In 2015, the National Development and Reform Commission (NDRC) and Ministry of Industry and Information Technology (MIIT) jointly issued the New Investment Electrified Vehicles Corporation Management Regulation, which served as the basis for EV production permits. Securing a permit was the first step for automakers seeking to sell EVs and receive government subsidies. Foreign automakers were also required to set up joint ventures with 50:50 stakes in the country. This restriction was lifted for EV manufacturing in 2018 and for commercial vehicles in 2020, and it is scheduled to be lifted for all vehicles in 2022.

Did the Program Succeed?

The combination of a clear national strategy to develop EVs and batteries and specific policies and financial support to sustain it, has boosted EV uptake significantly. China's share of total EVs sold globally rose from 3 percent in 2011 to 26 percent in 2015 and exceeded 50 percent in both 2018 and 2019. China is and will continue to be the world's largest country market for the next decade or more based on annual sales and fleet size for both passenger and commercial vehicles. The combination of policies ensured that Chinese automakers and battery manufacturers were able to scale. As overall EV sales have surged in China, domestic automakers have reaped the benefits. Among the top 10 manufacturers serving the market from 2011–2019, just two were not entirely Chinese-owned: California-based Tesla Motors and a SAIC-General Motors joint venture. Shenzhen-based BYD topped the list, followed by Beijing-based BAIC. The combination of national and local policies has also led to Chinese battery manufacturers establishing themselves as top-tier suppliers. China's CATL was the world's largest supplier of batteries for EVs and for stationary storage in 2019.

The CHAIRMAN. Thank you very much.

Finally, we are going to hear from Dr. Lara Pierpoint.

Dr. Pierpoint.

STATEMENT OF DR. LARA M. PIERPOINT, DIRECTOR, CLIMATE, ACTUATE

Dr. PIERPOINT. Thank you, thank you so much.

Thank you, Chairman Manchin, Ranking Member Barrasso and members of the Committee for the opportunity to speak with you today.

I have devoted my career to energy and climate technology innovation and infrastructure deployment. I've done so from many positions: first, from academia; second, as a Science Fellow for this Committee in 2013; from DOE, itself; from Exelon, a Fortune 100 electricity utility where I ran the technology R&D program. Now I'm doing so from the vantage of a non-profit called Actuate where I seek to accelerate greenhouse gas emissions reductions. In each of these roles I have worked extensively with the Department of Energy and I've learned a lot about DOE's strengths and weaknesses. I think as we talk about innovation and competitiveness today, it's important to anchor in the question of why we innovate. In my world, it's to help save the climate, but I think we can all hopefully acknowledge that whatever our opinions on climate, the fact of the matter is that the world is beginning to demand products and services that enhance sustainability. As the United States we have a choice. We can participate in that economy and reap the benefits of the jobs and everything else that comes along with that or we can sit this out.

Today, I'll do two things. First, I'll describe how the Office of Science is critical to this mission of competitiveness and innovation. Second, I will highlight three things the Department of Energy can do at the later stages of the technology innovation pipeline to build on the work of this Committee and the great infrastructure already at DOE for technology transfer and impact.

The Office of Science truly matters. It's important to robustly fund science and basic science in particular because this is where new ideas come from. Ownership of that piece of the value chain is critical for the United States. Fusion here represents a very important example in the process of playing out before our eyes as we speak. Sustained investments by the Office of Science over decades have led to scientific and engineering breakthroughs in recent years that are making fusion energy more possible than it has ever been, but we need to do more to help get technologies like fusion across the finish line. This is why the Department of Energy must do more to move beyond the paradigm of technology transfer into holistic technology impact. Many of us live with a great American fantasy that the government supports basic science and technology development and then throws those technologies over the transom for the private sector to pick up and commercialize. It almost never works that simply.

At Exelon, I had a very unique set of resources to bring to bear on commercialization challenges. It started, most importantly, with leadership at Exelon that had strong vision toward innovation and how innovation could be valuable for the company. With that, I was able to manage a team with deep technical expertise. I had a mandate to place small bets and make investments in technologies of potential value to the company and I was able to sign overarching research agreements with several institutions, including universities and national labs. But still, even with all these resources to bring to bear, which are unique among utilities, we faced challenges finding technologies in which to invest and we faced challenges taking even the best ones across the finish line to really reap commercial value from them. The specific issues varied across technologies, but these included challenges finding researchers and institutions with commercial mindsets, issues where the cost of taking the next step was too high, challenges in that it took a year and sometimes more to negotiate contracts with Department of Energy and the labs and that was just to get started and silos that abound both within our companies and within the Department of Energy.

I know that this Committee sees these challenges and I applaud all of you for authorizing the Office of Technology Transitions in the Energy Act last year. There's still work to be done so I offer suggestions to continue to build on the incredible infrastructure DOE has to have technology impact. First, I would suggest that DOE does more to encourage partnering and also potentially to set metrics, specifically related to the potential for commercial value among the research it sponsors. Second, I recommend that the Department of Energy overhaul its contracting systems. I understand it's important for us to protect the taxpayer in the context of these negotiations, but the taxpayer benefits far more from commercialized technologies and jobs than it does from things like DOE ownership of intellectual property. Finally, I suggest that the Department fund a much more complete suite of entities to universities and labs, but also non-profits and others that can really bring to bear holistic pieces of the solution. This is what we do at Actuate, where I am now. We work on greenhouse gas reduction by bringing a full suite of actors under the tent to demonstrate systems level solutions.

While these recommendations by themselves won't solve all of our technology commercialization challenges, I think they're an important start, again, for building on the infrastructure at DOE. With that, I thank you and look forward to your questions.

[The prepared statement of Dr. Pierpoint follows:]

Actuate

Lara M. Pierpoint, Ph.D.
Director, Climate
Actuate

Statement on the leading role of the Department of Energy in American energy innovation and how its research, development, demonstration, and deployment programs may be enhanced to further boost the economic competitiveness of the United States

Before the Senate Committee on Energy and Natural Resources
April 15, 2021

Chairman Manchin, Ranking Member Barrasso, and Members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to speak with you today regarding the Department of Energy and its crucial role in advancing American innovation and competitiveness.

I have devoted my career to energy and climate technology innovation and infrastructure deployment. I have done so from many different positions: first, from academia, where I modeled options for nuclear waste management under my Ph.D. advisor, former Energy Secretary Ernest Moniz. Next, I worked on nuclear energy, efficiency, storage, and energy finance issues for this committee, as a Science Fellow with Senator Wyden in 2013. In my next role, I administered grants, wrote policy proposals, and managed analysis on natural gas, coal, nuclear, and grid cybersecurity issues at the U.S. Department of Energy (DOE). Finally, I served as Director of Technology Strategy for Exelon, a Fortune 100 energy utility, where I ran the company's partnership R&D program and invested in early-stage technologies. While there, I helped the company leverage tens of millions of dollars in Federal and State funding to support its innovation agenda. Now, I helm the climate work at a new nonprofit called Actuate, working to break open new approaches to the scaleup and deployment of greenhouse gas-reducing infrastructure.

I have worked with the DOE as an academic, as an employee, and as part of a large corporation seeking to innovate. In the process, I have experienced first-hand DOE's greatest strengths and its biggest challenges in spurring innovation.

Effective innovation requires more than the right processes and resources. It requires a clear mission; a North Star that mobilizes and excites the best minds to serve our country. DOE has some of the most valuable assets to bring to bear in the global fight against climate change, and its work is crucial for creating sustainable energy solutions that enhance infrastructure resilience, in an equitable and cost-effective way. DOE's success contributes to fighting climate change, and enhances the nation's global economic standing. And these important missions are closely linked.

We are not here to debate climate science. I hope we can all acknowledge, however, the economic reality it creates, that global demand for sustainability-minded and greenhouse gas-reducing technologies and infrastructure is on the rise. The U.S. has a choice: lead in climate technology innovation, and make sustainability products here, or cede leadership, jobs, and manufacturing to the rest of the world.

Today, I will highlight how the DOE Office of Science and ARPA-E are contributing strongly to climate innovation and global leadership. This in no way diminishes the contributions of the DOE program offices; they include a wide variety of efforts that are critical to achieving our national goals. Second, I will offer suggestions on additional activities DOE should undertake to expand its impact, translating innovations to economic gains for our nation.

Celebrate Achievements: The Office of Science and ARPA-E

The DOE's Office of Science is a national treasure. It is the largest federal sponsor of physical science research, and it is a key reason why I stand before you today.[1] In college, I had the privilege of working with a team at Lawrence Berkeley National Laboratory on work at Brookhaven National Laboratory's Relativistic Heavy Ion Collider. We studied quark-gluon plasma, an esoteric form of matter that represents what the universe was made of when it was first born. The experience riveted me, and cemented my decision to pursue a career in science and engineering.

It may seem as though a fundamental understanding of the physics of matter is a long way from establishing manufacturing lines and boosting GDP. But there are many ways in which Office of Science programs are starting to bear fruit, and fusion is one example. When I started my graduate studies in 2005, fusion was "30 years away, and always would be." That is no longer true. In its report "Bringing Fusion to the U.S. Grid," the National Academies of Sciences, Engineering, and Medicine recommended building a pilot fusion facility, showing net energy production at low cost, between 2035 and 2040.[2]

That may still seem far away, but the fact that we have a pathway to an always-on, carbon-free, environmentally friendly source of energy in the next two decades is game-changing for the climate challenge and for our economy. At Exelon, when I described advancements in fusion with our senior leadership, I was concerned they would be dismissed as too far in the future. Instead, I was told that as a nuclear company, Exelon needed to track these developments. This is not the same as voting with corporate investment dollars, but it is an important step on that path, and a signal that we are on a different plane of readiness and excitement with respect to contributions from fusion energy.

[1] https://www.energy.gov/science/mission, April 12, 2021.
[2] National Academies of Sciences, Engineering, and Medicine. 2021. Bringing Fusion to the U.S. Grid. Washington, DC: The National Academies Press. https://doi.org/10.17226/25991.

ARPA-E represents one of the best examples of innovation machinery that DOE brings to bear on the climate challenge. ARPA-E programs range from open calls to focused efforts to develop technologies with certain characteristics, and they have resulted in, by ARPA-E's estimation, 88 new startups and $4.9 billion in follow-on funding.[3] Program managers, recruited and retained in the rotating style honed at DARPA, are some of the best minds in energy innovation work. ARPA-E demonstrates that DOE can find new and powerful ways to do business, and continues to evolve in important ways as an organization. One prime example includes ARPA-e implementing its SCALEUP program to support continued evolution of the technologies in its portfolio; DOE should do more of exactly this type of work. Furthermore, given ARPA-E's proven effectiveness, it is time for Congress to fund ARPA-E at a significantly higher level. ARPA-E receives far more excellent funding applications than it can support, and has proven its model.

Do More to Achieve Impact: Moving the Department of Energy Beyond the Technology Transfer Paradigm to Technology Impact Delivery

Just as important as supporting the early stages of the innovation pipeline is supporting the transition of technologies from laboratories into wide-scale use. The words "technology transfer" are actually somewhat a misnomer. They imply that the government does the hard work of basic science, early technology development, and proof, and then neatly hands the technology off to the private sector to turn it into a product, scale it, and deploy it. I can't think of a single example among energy and climate technologies where the process has worked that simply.

The Office of Technology Transitions was established at DOE in 2015 to work on these issues. It has done herculean work as it aims to expose national laboratory and other DOE-funded technologies to commercial partners and deploys its $30 million Technology Commercialization Fund created by this committee in the Energy Policy Act of 2005. For the last few decades, Congress has recognized the complicated nature of technology development and has provided guidance to DOE on how to improve the innovation process. I commend the committee for its work to officially authorize the Office of Technology Transitions and to elevate the role of its Director to Chief Commercialization Officer and Advisor to the Secretary in last year's Energy Act of 2020. The law provides important direction to DOE on commercialization and entrepreneurship activities of the office and to commercialization efforts across the Department.

But the gap between what DOE funds, through its energy offices and ARPA-E, and what the private sector will fund and build, is still far too wide. A very select few venture capitalists, philanthropists, and "hardtech incubators" are stepping up with some patient capital and some technology de-risking resources. But it is not nearly enough. At this moment, with fierce global competition, the urgent need to mitigate climate change, and major hurdles to be overcome for many of the most important energy and climate innovations we have, everyone in the innovation ecosystem must do more to help technologies emerge from labs and universities such that they can be quickly harnessed and deployed. DOE, with its user facilities and world-class expertise,

[3] https://arpa-e.energy.gov/about/our-impact, accessed April 11, 2021.

funding resources, and programmatic design, has the potential to play a much better catalytic role in translating climate and energy innovation into economic impact.

At Exelon, I oversaw a team of PhDs with a set of abilities and a mandate that remains unique in the utility industry. We had an explicit mission to source new technology ideas that could be beneficial to the company, and to invest through a variety of means. We created overarching research agreements with universities and funded projects at each, we signed a Cooperative Research and Development Agreement with Argonne National Laboratory and funded work there, we made early-stage equity investments, and we partnered on and received DOE grants. We did all this in support of a broad innovation community federated at each of Exelon's business units, with a strong innovation push from the highest levels of our company's leadership. Few utilities have similar resources, support, and vision.

Even with these remarkable assets, we struggled at times to find projects that matched our interest and criteria, and to realize value from the ones that did. Most universities and national laboratories have strong scientific missions, and reward systems for researchers are based on papers published and frontiers expanded. My team, however, sought something very different: we looked for a specific line of sight toward commercial value for our company with every project we funded. With some notable exceptions, we had a very difficult time finding individuals and institutions that could frame and conduct their research in that way. In addition, the time it took to sign research contracts with DOE and overarching research agreements with universities was far too long; it was often a year or more just to get started.

Most importantly, we struggled to identify a sensible pathway to support technologies as they emerged from the lab into commercial use. While we had some unique abilities to place "small bets" on relatively early-stage technologies, we found it much harder to consistently justify the extensive investments required to fully de-risk those technologies in the later stages of the commercialization pipeline. Some technologies, including some that we funded, are lucky enough to find patient venture capital or homes in incubators with an ability and willingness to help them develop and scale. But there are too few dollars and too few opportunities for worthy technologies in this space, and DOE can do more beyond loan guarantees and demonstration programs to fix this section of the innovation pipeline.

This is an especially challenging set of problems to address, because almost no two technologies or commercialization approaches are alike, and neither are the barriers they face. Sometimes, the next steps in technology de-risking are too expensive for the private sector to fund. Sometimes, it's not yet clear what the market demand is. In some cases, the approach is so novel that it requires regulatory changes that utilities justifiably expect will be slow. Sometimes, the reduction in financing costs afforded by the DOE loan programs is just what a project needs, but we need more tools in this toolkit. This is exactly the set of problems I am addressing at Actuate. If the United States is to be successful in our bid for global sustainability and American competitiveness, DOE, with its very different set of approaches and assets, needs to address them as well.

There are several things DOE can do to improve the ecosystem for technology transitions, increase the rate at which DOE laboratory-created technologies emerge into the private sector and begin to have impact, and ultimately improve our competitive posture.

First, DOE should narrow the daylight between its work and the private sector, by encouraging collaboration, and, ideally, by instituting a cultural shift toward an economic impact mindset. Over the last several years, many DOE funding opportunities have included helpful requirements for private sector collaboration. This meant that at Exelon, we benefited greatly from a steady stream of lab scientists, university researchers, and startups seeking our ideas and participation as they pursued federal funding. And we believe they benefited from our commercial perspective. Incrementally, DOE could encourage a range of collaborative activities, from encouraging private sector cost share, to prioritizing funding projects that set companies as formal advisors. Note that DOE should *not* be held to a blanket directive that all funding opportunities include private sector cost share requirements. There are many cases where ideas are valid but need more de-risking to attract private sector funding, or where other forms of contribution from the private sector are in fact more valuable.

Transformationally, DOE should overhaul the guidelines and incentives embedded in the funding it grants to labs and universities. While direct private sector partnering may not be relevant for all DOE programs, especially those in the Office of Science, the entire Department would benefit from changes in how it prioritizes funding and rewards success. More programs could explicitly set engineering and cost targets. Success metrics should expand from papers published to include patents pursued and transferred, private sector follow-on funding attracted, and companies created. The degree to which these changes are desirable is different for each laboratory and each technology area, and should not be applied in a manner that stifles very early-stage scientific creativity. But new criteria that foster a cultural shift within laboratories and universities toward climate and economic impact will strengthen the U.S. innovation and competitiveness posture.

Second, DOE should do much more to specifically foster entrepreneurship. New ideas like the “LabStart” concept piloted at the National Renewable Energy Laboratory last year help pair lab researchers and entrepreneurs, enabling the labs to bring technologies and “CTO services” to new companies. And Lawrence Livermore National Laboratory created an Impact Committee to advise its Carbon Initiative, on which I serve. The committee presents a unique opportunity for those of us with commercialization credentials to hear from lab scientists and help steer their work toward making a difference. Supporting these kinds of activities is feasible immediately, and will provide much-needed progress toward improving commercialization opportunities within the labs.

As another driver for transformational impact of innovation, DOE should dramatically deepen and expand its support for entrepreneurial R&D fellowships. Entrepreneurial fellowships, which originated at Lawrence Berkeley National Laboratory's Cyclotron Road, have proven to serve as a lifeline for nascent technologies as well as deliver an invigorating influx of new ideas to the lab itself. Further enhanced and scaled through the national non-profit Activate.org, the fellowship program has already delivered extremely attractive results; by their analysis, they have nearly 100 new products and businesses and catalyzing hundreds of millions of dollars in follow-on private sector funding. The initial program has also been repeated, in locally tailored ways, by Argonne as Chain Reaction Innovations and Oak Ridge National Lab as Innovation Crossroads. The DOE should scale these programs like it across the Department and country. Doing so is inexpensive at the level of the DOE budget, and would have massive catalytic effects in transforming scientists into entrepreneurs, invigorating the laboratories, and accelerating the commercialization of the technologies we need to address climate change and strengthen our economy.

Third, DOE must overhaul its contracting and reporting processes. While some commercial entities, like Exelon, have time and staff to conduct year-long negotiations on collaborative research and then painstakingly report how every federal dollar is spent, there are far more commercial entities that do not. Goals like protecting intellectual property on behalf of the American people are laudable and important and should continue to receive due consideration. But China and the climate are not waiting while we negotiate with ourselves.

Furthermore, the American people benefit far more from the installation of clean infrastructure and the sale of real products than they do from lab or DOE ownership of intellectual property. Programs like the Office of Energy Efficiency and Renewable Energy's Small Business Voucher pilot are examples of how DOE can overhaul its contracting, making it easier to work with the DOE labs. Of the 114 small businesses in the pilot, 91 percent of awardees rated positively the speed with which they were able to sign contracts with a national lab. This was due to a concerted effort to streamline the contracting process and create a central application portal and consolidated access to lab resources and capabilities.[4] New funding and contracting rules should explicitly encourage and support commercialization rather than hinder it; should be designed to move at the speed of real innovation; and should emphasize outcomes-based reporting that clearly delineates what the taxpayer gets for dollars spent.

Fourth, DOE should expand on one of the greatest strengths it possesses within the national labs: its user facilities. The national laboratories have unique assets that should continue to support basic science research, but be available to commercial entities as well. Within the nuclear sector, the National Reactor Innovation Center (NRIC) and Gateway for Accelerated Innovation in Nuclear (GAIN) programs are offering valuable opportunities to the companies working to commercialize advanced reactors. Efforts like NRIC's creation of an advanced reactor testbed should be fully funded, in a manner that includes continued operational support so NRIC can serve the community in a predictable manner. DOE should do much more to assess private sector needs and build the testbeds that specifically meet them.

[4] Gretchen Jordan and Albert Link, Evaluation of U.S. DOE Small Business Vouchers Pilot (Washington, D.C.: DOE, November 2018), 37, https://www.energy.gov/sites/prod/files/2018/12/f58/eval-small-business-vouchers-pilot-112718.pdf.

Fifth, the Office of Technology Transitions needs to be prioritized and resourced appropriately. Its Technology Commercialization Fund (TCF), currently at $30 million per year, is not nearly enough to support the commercialization of the outcomes of nearly $9 billion in federal work across DOE's Office of Science and Energy Program offices at the national labs. In addition to more funding for the TCF, a tripling of the OTT budget from approximately $20 million in FY 2021 to $60 million would be a good start toward implementing the suggestions made above. The additional funding could go to additional investments outlined in the Energy Act of 2020, like commercialization activities, partnerships to ensure success of DOE demonstration programs, surveys and other engagement mechanisms to systematically identify commercialization challenges within the private sector, regional innovation, and a range of other activities in support of new contracting mechanisms and DOE program incentives.

A transformational step forward could include funding a DOE foundation focused on technology impact. A foundation might enable new sources of funding to work alongside DOE priorities, and could enable DOE to find creatively powerful new ways to partner with the private sector. The Increasing and Mobilizing Partnerships to Achieve Commercialization of Technologies for Energy Act" or the "IMPACT for Energy Act," S.2005 introduced in the 116th Congress by Senators Chris Coons (D-DE) and Lindsey Graham (R-SC) establishes such a foundation. Its companion bill, H.R. 3575, passed in the House of Representatives last year, is a bipartisan bill with strong support by private sector and philanthropic partners. The concept has also been thoroughly evaluated by the National Academy of Public Administration, which recommends the creation of a DOE Foundation in its recently released report, *An Innovation Foundation for DOE: Roles and Opportunities*.

Sixth, DOE, and ideally the entire government, should do all of this in a systems context, with more funding going toward cross-cutting projects and new players: not just universities and labs, but also nonprofits, equity-focused community organizations, and regulators. The truth is that the silos we have established in government, in corporations, and in our economy are not suited to the interconnected and global challenges we face. This is true for pandemics and it is especially true for climate change.

My organization, Actuate, aims to solve some of the thorny systems issues that bedevil climate change mitigation and defy the boundaries of our silos. We start by asking where the biggest levers are to reduce greenhouse gases. We then get very specific about what the barriers are to wide-scale, rapid deployment of those levers. If we see a bold goal tied to greenhouse gas reduction, paired with a unique opportunity to demonstrate something that might just barely be achievable, we have the core elements of an Actuate program. We are early in our journey, but we have nascent ideas that range from reducing nitrogen emissions from agriculture, to demonstrating deep, consistent demand response to backstop renewables. Over the coming year, we intend to explore these ideas, designing programs that will actively fund the full suite of actors that are needed to achieve scale. This includes universities, labs, and startups, but also community organizations, nonprofits, and the companies and financial institutions that will bring much of the infrastructure into reality. Our hope is that these actions will, among other things, provide a working example of new ways in which federal agencies can support innovation in a systems context.

These recommendations are raw ideas that require further study before implementation. Collectively, they and other measures will not move DOE beyond the dated technology transfer paradigm, but they represent a start toward catalyzing more, faster impact-driven innovation and investment.

In conclusion, we should celebrate the incredible asset we have in DOE and the national laboratories in fighting climate change and promoting American competitiveness. DOE enabled one of my proudest moments at Exelon: my team's launching of a hydrogen electrolysis pilot project at a nuclear plant site, intended to demonstrate a pathway for regional supply of clean hydrogen. That project became possible thanks to Federal ingenuity and funding, and foresight by Exelon's leadership. We need many, many more examples like it up and down the innovation pipeline and across technologies. Doing so will enable us to claim American leadership in science and technology development as we deliver climate-preserving infrastructure to the world.

Chairman Manchin, Ranking Member Barrasso, and Members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to appear before you today to discuss the Department of Energy and its role in U.S. innovation and competitiveness. I look forward to your questions.

The CHAIRMAN. Thank you, Dr. Pierpoint.

Now we are going to begin with our questions.

My first question is going to go to both Dr. Mason and Mr. Dabbar. So, the Department of Energy and national labs bring incredible expertise, as you all just pointed out, infrastructure, and resources to bear on many technological challenges facing our country. Our Committee often discusses the application of their R&D activities to energy issues, but we know that their capabilities extend far beyond energy. So, my question would be for each of you. Of the following technologies could you please state whether DOE or the national labs work on these ten R&D areas? The first one would be artificial intelligence.

Dr. MASON. Yes, absolutely.

Mr. DABBAR. Yes, Senator.

The CHAIRMAN. Yes, okay.

Quantum computing?

Dr. MASON. Yes.

Mr. DABBAR. Yes, Senator.

The CHAIRMAN. High performance computing and semiconductors?

Dr. MASON. Core competencies for us, yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Robotics, automation and advanced manufacturing?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Natural or human-caused disaster prevention?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Advanced communications technology?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Biotech, genomics and synthetic biology?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Cybersecurity and data storage?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Advanced materials science and engineering?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. Advanced engineering and industrial strategy—efficiency?

Dr. MASON. Yes.

Mr. DABBAR. Yes.

The CHAIRMAN. And this one could be for the entire panel and we will just start with Dr. Ladislaw and whoever wants to answer.

Over the past decades the most innovative technologies have come out of agencies that have worked together toward common goals, that includes DoD, NASA, NSF and DOE and their networks including the national labs, defense labs and our outstanding universities and partners in the private sector. Each agency has harnessed its strengths and combines federal funding and private capital to successfully pair fundamental research with commercialization efforts. In the context of global competition, I want to see each federal agency, research agency, made stronger, funded adequately for the challenges we face and well-coordinated across government and I want to avoid reinventing the wheel at any one point. So, from each of your perspectives, can you highlight the role DOE and the national labs have in technology development and commercialization and how that contrasts with the role that the National Science Foundation currently plays?

Mr. DABBAR. I'll go ahead and start, Senator.

The CHAIRMAN. Okay, go ahead.

Mr. DABBAR. So the way I would characterize the National Science Foundation versus DOE, the National Science Foundation has a much broader, but also much more focused on early, early investment, especially within university systems, to a large degree. And so, they're more on the academic and a bit more on the discovery side. DOE strengths, certainly the national lab complex is probably the biggest core. The national labs allow scale for facilities and for research that not even Harvard and Stanford with their endowments can even come close to replicating in terms of the facilities and the capabilities. And those facilities allow for focus for people from all over the country and even all over the world to come together and to use those facilities to drive things in those particular areas that you asked for.

The CHAIRMAN. Let me be more direct. Dr. Thomas, if $100 billion is invested in the National Science Foundation would they be able to use that or would they be duplicating what has already been done or would it just basically be trying to reinvent the wheel?

Dr. MASON. I think it's really important to understand the differences in nature of how these agencies operate. The National Science Foundation is outstanding at funding a very diverse range of activities in a very much bottoms up, individual investigator-driven mode. That's the great strength of the American academic research enterprise.

The Department of Energy and the national labs and actually many other government agencies that have, you know, mission areas, where they have to deliver outcomes to the American taxpayer, you know, focus on those mission activities and use them to, you know, drive the development of science and technology, particularly as you get closer to the point of application that mission focus is really important. Obviously, with DOE its energy, its national security or nuclear deterrent and we work with those outcomes in mind. I'd like to say at Los Alamos, it always starts with the science, but we don't stop with the science. We don't stop with the publications. We have to get things deployed, whether it's deployed into the energy sector or deployed in the form of a deterrent that is handed off to the Department of Defense. And that is a fundamental difference in how the agency approaches things and when you look at the scale of the problems, the list that you just outlined, these are really, really tough problems. We need to mobilize all of the R&D assets, recognizing the different strengths of the agencies involved, coordinating to make sure that we've got the right assignments in the right places.

And I think if we do that, then we will be very well positioned for the future.

The CHAIRMAN. Ms. Ladislaw, do you have anything you want to add to that?

Ms. LADISLAW. The only thing I would add is—money is good, but strategy is better. So it's not enough just to pay different places to do different things. It's what's—what are we going to do to actually be competitive in deploying these technologies? And I think putting the, sort of, you know, the full suite of the energy innovation ecosystem on the table in terms of planning is really what's important here.

The CHAIRMAN. Senator Barrasso.

Senator BARRASSO. Well, thanks so much, Mr. Chairman.

I want to follow up on that exact same line of questioning and start with Mr. Dabbar because yesterday the Commerce Committee discussed a proposal to establish this new directorate of technology at the National Science Foundation. This directorate is going to focus on ten fields including—and it's the things that Senator Manchin just mentioned here—advanced energy, high performance computing, cybersecurity, advanced manufacturing, materials science and engineering. You can see all the things that are listed there and people on the screen can see them as well. These are fields that the Department of Energy is already doing significant work in, as illustrated right here by this chart.

In your view, is duplicating the work of the Department of Energy an efficient and responsible use of taxpayer dollars?

Mr. DABBAR. I do think that if DOE or any other agency is already heading down the road on, for example, lots of advanced energy proposals, I would argue that DOE's pretty good at advanced energy, amongst many of the other areas, that trying to find the strengths associated with each is better. I think an example of what this Committee has done well, and the interagency, has been the National Quantum Initiative where everyone found a role. DOE had a role, Commerce had a role, and NSF had a role, and there was no duplication.

Senator BARRASSO. Dr. Mason, is there anything you would like to add to that in terms of does it make sense to duplicate the work of the Department of Energy as Senator Manchin just asked about too?

Dr. MASON. I think the thing that's important is to recognize the complementary nature of the institutions and the different things they can bring to solving these problems. You know, certainly there is value in different approaches, different ways of thinking about tough problems and, you know, there are strengths within the academic community that we absolutely need to leverage, but I think as a mission agency the Department can focus on those outcomes and there is an important distinction there in the sense that within the national labs we can mobilize large groups of people to work in problems, on problems and define their work product and where they're headed. Academic institutions are better suited to freedom of ideas. It can be more difficult to mobilize a large number of people and have them all move in the same direction, which is a particular strength of the national labs.

Senator BARRASSO. Mr. Dabbar, last Friday the Director of National Intelligence released their report titled "Annual Threat Assessment of the U.S. Intelligence Community." It just came out this past week. I am going to go to the part of it where it says, "China will remain the top threat." "China will remain the top threat to U.S. technological competitiveness." It goes on to say, "Beijing uses a variety of tools from public investment to espionage and theft," and theft, "to advance its technological capabilities."

Could you please describe for the Committee the tactics that China uses to steal our research results?

Mr. DABBAR. Yes, yes, Senator.

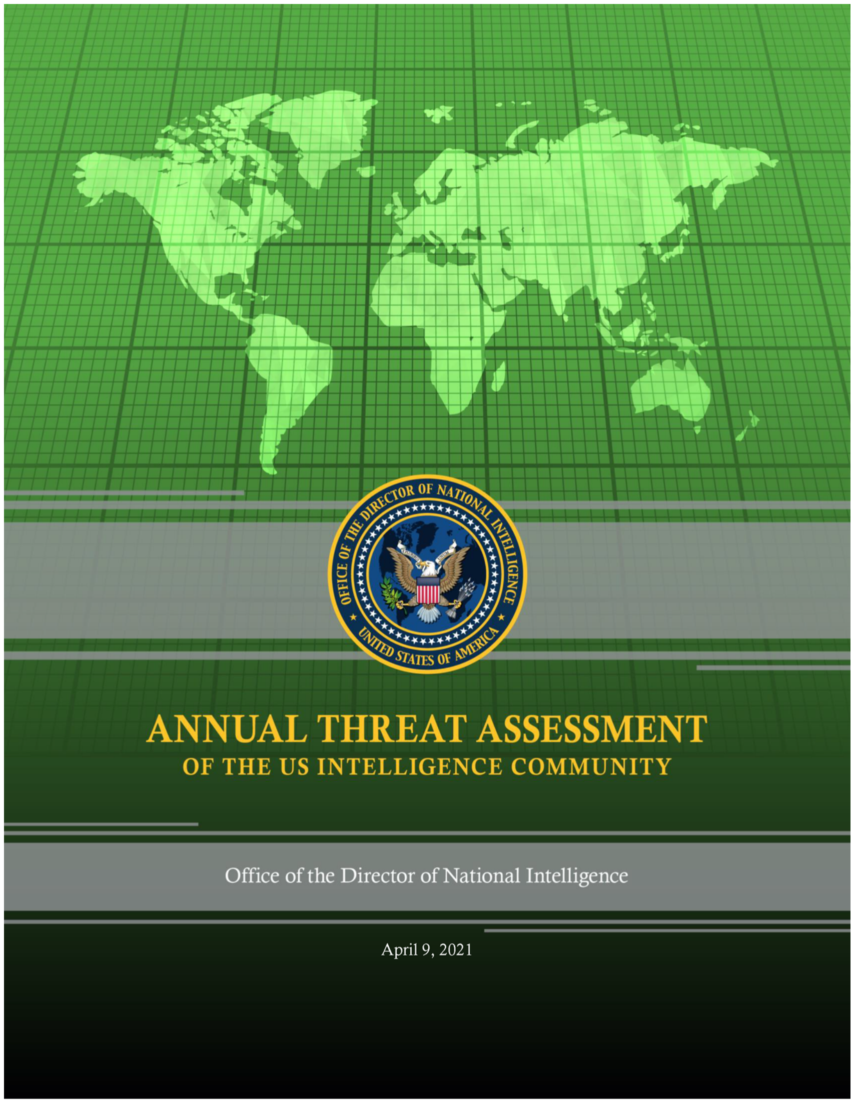
When I was at DOE, we saw this incredible ramp up by China in their efforts in terms of spying and trying to steal technology. One example is that they tried to buy their way in to participation in science efforts, in large part, in many of the instances to get manufacturing and fabrication knowledge of major pieces of equipment that they don't know how to build and they try to place their scientists within those research areas to try to get access associated with that fabrication. So that's one of many, many different examples of what they——

Senator BARRASSO. Just the tip of the iceberg there.

Mr. Chairman, I ask unanimous consent to enter into the record this report from the Director of National Intelligence.

The CHAIRMAN. Without objection.

[Annual Threat Assessment of the U.S. Intelligence Community report referred to follows:]


OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE
UNITED STATES OF AMERICA
ANNUAL THREAT ASSESSMENT
OF THE US INTELLIGENCE COMMUNITY
Office of the Director of National Intelligence
April 9, 2021

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INTRODUCTION

This annual report of worldwide threats to the national security of the United States responds to Section 617 of the FY21 Intelligence Authorization Act (P.L. 116-260). This report reflects the collective insights of the Intelligence Community (IC), which is committed every day to providing the nuanced, independent, and unvarnished intelligence that policymakers, warfighters, and domestic law enforcement personnel need to protect American lives and America's interests anywhere in the world.

This assessment focuses on the most direct, serious threats to the United States during the next year. The order of the topics presented in this assessment does not necessarily indicate their relative importance or the magnitude of the threats in the view of the IC. All require a robust intelligence response, including those where a near-term focus may help head off greater threats in the future, such as climate change and environmental degradation.

As required by the law, this report will be provided to the congressional intelligence committees as well as the committees on the Armed Services of the House of Representatives and the Senate.

Information available as of 9 April 2021 was used in the preparation of this assessment.

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FOREWORD

In the coming year, the United States and its allies will face a diverse array of threats that are playing out amidst the global disruption resulting from the COVID-19 pandemic and against the backdrop of great power competition, the disruptive effects of ecological degradation and a changing climate, an increasing number of empowered non-state actors, and rapidly evolving technology. The complexity of the threats, their intersections, and the potential for cascading events in an increasingly interconnected and mobile world create new challenges for the IC. Ecological and climate changes, for example, are connected to public health risks, humanitarian concerns, social and political instability, and geopolitical rivalry. The 2021 Annual Threat Assessment highlights some of those connections as it provides the IC's baseline assessments of the most pressing threats to US national interests, while emphasizing the United States' key adversaries and competitors. It is not an exhaustive assessment of all global challenges and notably excludes assessments of US adversaries' vulnerabilities. It accounts for functional concerns, such as weapons of mass destruction and technology, primarily in the sections on threat actors, such as China and Russia.

Beijing, Moscow, Tehran, and Pyongyang have demonstrated the capability and intent to advance their interests at the expense of the United States and its allies, despite the pandemic. China increasingly is a near-peer competitor, challenging the United States in multiple arenas—especially economically, militarily, and technologically—and is pushing to change global norms. Russia is pushing back against Washington where it can globally, employing techniques up to and including the use of force. Iran will remain a regional menace with broader malign influence activities, and North Korea will be a disruptive player on the regional and world stages. Major adversaries and competitors are enhancing and exercising their military, cyber, and other capabilities, raising the risks to US and allied forces, weakening our conventional deterrence, and worsening the longstanding threat from weapons of mass destruction.

The effects of the COVID-19 pandemic will continue to strain governments and societies, fueling humanitarian and economic crises, political unrest, and geopolitical competition as countries, such as China and Russia, seek advantage through such avenues as "vaccine diplomacy." No country has been completely spared, and even when a vaccine is widely distributed globally, the economic and political aftershocks will be felt for years. Countries with high debts or that depend on oil exports, tourism, or remittances face particularly challenging recoveries, while others will turn inward or be distracted by other challenges.

Ecological degradation and a changing climate will continue to fuel disease outbreaks, threaten food and water security, and exacerbate political instability and humanitarian crises. Although much of the effect of a changing climate on US security will play out indirectly in a broader political and economic context, warmer weather can generate direct, immediate impacts—for example, through more intense storms, flooding, and permafrost melting. This year we will see increasing potential for surges in migration by Central American populations, which are reeling from the economic fallout of the COVID-19 pandemic and extreme weather, including multiple hurricanes in 2020 and several years of recurring droughts and storms.

The scourge of illicit drugs and transnational organized crime will continue to take its toll on American lives, prosperity, and safety. Major narcotics trafficking groups have adapted to the pandemic's challenges to maintain their deadly trade, as have other transnational criminal organizations.

Emerging and disruptive technologies, as well as the proliferation and permeation of technology in all aspects of our lives, pose unique challenges. Cyber capabilities, to illustrate, are demonstrably intertwined with threats to our infrastructure and to the foreign malign influence threats against our democracy.

ISIS, al-Qa'ida, and Iran and its militant allies continue to plot terrorist attacks against US persons and interests, including to varying degrees in the United States. Despite leadership losses, terrorist groups have shown great resiliency and are taking advantage of ungoverned areas to rebuild.

Regional conflicts continue to fuel humanitarian crises, undermine stability, and threaten US persons and interests. Some have direct implications for US security. For example, the fighting in Afghanistan, Iraq, and Syria has direct bearing on US forces, while tensions between nuclear-armed India and Pakistan remain a concern for the world. The iterative violence between Israel and Iran, the activity of foreign powers in Libya, and conflicts in other areas—including Africa, Asia, and the Middle East—have the potential to escalate or spread.

The 2021 Annual Threat Assessment Report supports the Office of the Director of National Intelligence's transparency commitments and the tradition of providing regular threat updates to the American public and the United States Congress. The IC is vigilant in monitoring and assessing direct and indirect threats to US and allied interests. As part of this ongoing effort, the IC's National Intelligence Officers work closely with analysts from across the IC to examine the spectrum of threats and highlight the most likely and/or impactful near-term risks in the context of the longer-term, overarching threat environment.

CHINA'S PUSH FOR GLOBAL POWER

The Chinese Communist Party (CCP) will continue its whole-of-government efforts to spread China's influence, undercut that of the United States, drive wedges between Washington and its allies and partners, and foster new international norms that favor the authoritarian Chinese system. Chinese leaders probably will, however, seek tactical opportunities to reduce tensions with Washington when such opportunities suit their interests. China will maintain its major innovation and industrial policies because Chinese leaders see this strategy as necessary to reduce dependence on foreign technologies, enable military advances, and sustain economic growth and thus ensure the CCP's survival.

- Beijing sees increasingly competitive US-China relations as part of an epochal geopolitical shift and views Washington's economic measures against Beijing since 2018 as part of a broader US effort to contain China's rise.
- China is touting its success containing the COVID-19 pandemic as evidence of the superiority of its system.
- Beijing is increasingly combining its growing military power with its economic, technological, and diplomatic clout to preserve the CCP, secure what it views as its territory and regional preeminence, and pursue international cooperation at Washington's expense.

Regional and Global Activities

China seeks to use coordinated, whole-of-government tools to demonstrate its growing strength and compel regional neighbors to acquiesce to Beijing's preferences, including its claims over disputed territory and assertions of sovereignty over Taiwan.

- China-India border tensions remain high, despite some force pullbacks this year. China's occupation since May 2020 of contested border areas is the most serious escalation in decades and led to the first lethal border clash between the two countries since 1975. As of mid-February, after multiple rounds of talks, both sides were pulling back forces and equipment from some sites along the disputed border.
- In the South China Sea, Beijing will continue to intimidate rival claimants and will use growing numbers of air, naval, and maritime law enforcement platforms to signal to Southeast Asian countries that China has effective control over contested areas. China is similarly pressuring Japan over contested areas in the East China Sea.
- Beijing will press Taiwan authorities to move toward unification and will condemn what it views as increased US-Taiwan engagement. We expect that friction will grow as Beijing steps up attempts to portray Taipei as internationally isolated and dependent on the mainland for economic prosperity, and as China continues to increase military activity around the island.
- China's increasing cooperation with Russia on areas of complementary interest includes defense and economic cooperation.

Beijing will continue to promote the Belt and Road Initiative (BRI) to expand China's economic, political, and military presence abroad, while trying to reduce waste and exploitative practices, which have led to international criticism. China will try to increase its influence using "vaccine diplomacy," giving countries favored access to the COVID-19 vaccines it is developing. China also will promote new international norms for technology and human rights, emphasizing state sovereignty and political stability over individual rights.

China will remain the top threat to US technological competitiveness as the CCP targets key technology sectors and proprietary commercial and military technology from US and allied companies and research institutions associated with defense, energy, finance, and other sectors. Beijing uses a variety of tools, from public investment to espionage and theft, to advance its technological capabilities.

Military Capabilities

China will continue pursuing its goals of becoming a great power, securing what it views as its territory, and establishing its preeminence in regional affairs by building a world-class military, potentially destabilizing international norms and relationships. China's military commitment includes a multiyear agenda of comprehensive military reform initiatives.

- We expect the PLA to continue pursuing overseas military installations and access agreements to enhance its ability to project power and protect Chinese interests abroad.

- The PLA Navy and PLA Air Force are the largest in the region and continue to field advanced long-range platforms that improve China's ability to project power. The PLA Rocket Force's highly accurate short-, medium-, and intermediate-range conventional systems are capable of holding US and allied bases in the region at risk.

WMD

Beijing will continue the most rapid expansion and platform diversification of its nuclear arsenal in its history, intending to at least double the size of its nuclear stockpile during the next decade and to field a nuclear triad. Beijing is not interested in arms control agreements that restrict its modernization plans and will not agree to substantive negotiations that lock in US or Russian nuclear advantages.

- China is building a larger and increasingly capable nuclear missile force that is more survivable, more diverse, and on higher alert than in the past, including nuclear missile systems designed to manage regional escalation and ensure an intercontinental second-strike capability.

Space

Beijing is working to match or exceed US capabilities in space to gain the military, economic, and prestige benefits that Washington has accrued from space leadership.

- We expect a Chinese space station in low Earth orbit (LEO) to be operational between 2022 and 2024. China also has conducted and plans to conduct additional lunar exploration missions, and it intends to establish a robotic research station on the Moon and later an intermittently crewed lunar base.

- The PLA will continue to integrate space services—such as satellite reconnaissance and positioning, navigation, and timing (PNT)—and satellite communications into its weapons and command-and-control systems to erode the US military's information advantage.

Counterspace operations will be integral to potential military campaigns by the PLA, and China has counterspace-weapons capabilities intended to target US and allied satellites.

- Beijing continues to train its military space elements and field new destructive and nondestructive ground- and space-based antisatellite (ASAT) weapons.

- China has already fielded ground-based ASAT missiles intended to destroy satellites in LEO and ground-based ASAT lasers probably intended to blind or damage sensitive space-based optical sensors on LEO satellites.

Cyber

We assess that China presents a prolific and effective cyber-espionage threat, possesses substantial cyber-attack capabilities, and presents a growing influence threat. China's cyber pursuits and proliferation of related technologies increase the threats of cyber attacks against the US homeland, suppression of US web content that Beijing views as threatening to its internal ideological control, and the expansion of technology-driven authoritarianism around the world.

- We continue to assess that China can launch cyber attacks that, at a minimum, can cause localized, temporary disruptions to critical infrastructure within the United States.

- China leads the world in applying surveillance systems and censorship to monitor its population and repress dissent, particularly among ethnic minorities, such as the Uyghurs. Beijing conducts cyber intrusions that affect US and non-US citizens beyond its borders—such as hacking journalists, stealing personal information, or attacking tools that allow free speech online—as part of its efforts to surveil perceived threats to CCP power and tailor influence efforts. Beijing is also using its assistance to global efforts to combat COVID-19 to export its surveillance tools and technologies.

- China's cyber-espionage operations have included compromising telecommunications firms, providers of managed services and broadly used software, and other targets potentially rich in follow-on opportunities for intelligence collection, attack, or influence operations.

Intelligence, Influence Operations, and Elections Influence and Interference

China will continue expanding its global intelligence footprint to better support its growing political, economic, and security interests around the world, increasingly challenging the United States' alliances and partnerships. Across East Asia and the western Pacific, which Beijing views as its natural sphere of influence, China is attempting to exploit doubts about the US commitment to the region, undermine Taiwan's democracy, and extend Beijing's influence.

- Beijing has been intensifying efforts to shape the political environment in the United States to promote its policy preferences, mold public discourse, pressure political figures whom Beijing believes oppose its interests, and muffle criticism of China on such issues as religious freedom and the suppression of democracy in Hong Kong.

RUSSIAN PROVOCATIVE ACTIONS

***Moscow will continue to employ a variety of tactics this year meant to undermine US influence, develop new international norms and partnerships, divide Western countries and weaken Western alliances, and demonstrate Russia's ability to shape global events as a major player in a new multipolar international order*.** Russia will continue to develop its military, nuclear, space, cyber, and intelligence capabilities, while actively engaging abroad and leveraging its energy resources, to advance its agenda and undermine the United States.

We expect Moscow to seek opportunities for pragmatic cooperation with Washington on its own terms, and we assess that Russia does not want a direct conflict with US forces.

- Russian officials have long believed that the United States is conducting its own "influence campaigns" to undermine Russia, weaken President Vladimir Putin, and install Western-friendly regimes in the states of the former Soviet Union and elsewhere.

- Russia seeks an accommodation with the United States on mutual noninterference in both countries' domestic affairs and US recognition of Russia's claimed sphere of influence over much of the former Soviet Union.

Regional and Global Activities

We assess that Moscow will employ an array of tools—especially influence campaigns, intelligence and counterterrorism cooperation, military aid and combined exercises, mercenary operations, assassinations, and arms sales—to advance its interests or undermine the interests of the United States and its allies. We expect Moscow to insert itself into crises when Russian interests are at stake, it can turn a power vacuum into an opportunity, or the anticipated costs of action are low. Russia probably will continue to expand its global military, intelligence, security, commercial, and energy footprint and build partnerships with US allies and adversaries alike—most notably Russia's growing strategic cooperation with China—to achieve its objectives.

- We assess that Russia's Federal Security Service (FSB) organized the assassination of a Chechen separatist in a Berlin park in 2019 and tried to kill opposition activist Aleksey Navalnyy inside Russia in 2020 with a fourth-generation chemical agent.

- In the Middle East and North Africa, Moscow is using its involvement in Syria and Libya to increase its clout, undercut US leadership, present itself as an indispensable mediator, and gain military access rights and economic opportunities.

- In the Western Hemisphere, Russia has expanded its engagement with Venezuela, supported Cuba, and used arms sales and energy agreements to try to expand access to markets and natural resources in Latin America, in part to offset some of the effects of sanctions.

- In the former Soviet Union, Moscow is well positioned to increase its role in the Caucasus, intervene in Belarus if it deems necessary, and continue destabilization efforts against Ukraine while settlement talks remain stalled and low-level fighting continues.

- Since 2006, Russia has used energy as a foreign policy tool to coerce cooperation and force states to the negotiating table. After a price dispute between Moscow and Kyiv, for example, Russia cut off gas flows to Ukraine, including transit gas, in 2009, affecting some parts of Europe for a 13-day period. Russia also uses its capabilities in civilian nuclear reactor construction as a soft-power tool in its foreign policy.

Military Capabilities

We expect Moscow's military posture and behavior—including military modernization, use of military force, and the integration of information warfare—to challenge the interests of the United States and its allies. Despite flat or even declining defense spending, Russia will emphasize new weapons that present increased threats to the United States and regional actors while continuing its foreign military engagements, conducting training exercises, and incorporating lessons from its involvement in Syria and Ukraine.

- Moscow has the wherewithal to deploy forces in strategically important regions but the farther it deploys from Russia, the less able it probably will be to sustain intensive combat operations.

- Private military and security companies managed by Russian oligarchs close to the Kremlin extend Moscow's military reach at low cost, allowing Russia to disavow its involvement and distance itself from battlefield casualties. These proxy forces, however, often fail to achieve Moscow's strategic goals because of their limited tactical proficiency.

WMD

We assess that Russia will remain the largest and most capable WMD rival to the United States for the foreseeable future as it expands and modernizes its nuclear weapons capabilities and increases the capabilities of its strategic and nonstrategic weapons. Russia also remains a nuclear-material security concern, despite improvements to physical security at Russian nuclear sites since the 1990s.

- Moscow views its nuclear capabilities as necessary to maintain deterrence and achieve its goals in a potential conflict against the United States and NATO, and it sees a credible nuclear weapons deterrent as the ultimate guarantor of the Russian Federation.

- Russia is building a large, diverse, and modern set of nonstrategic systems, which are capable of delivering nuclear or conventional warheads, because Moscow believes such systems offer options to deter adversaries, control the escalation of potential hostilities, and counter US and allied troops near its border.

Cyber

We assess that Russia will remain a top cyber threat as it refines and employs its espionage, influence, and attack capabilities.

- Russia continues to target critical infrastructure, including underwater cables and industrial control systems, in the United States and in allied and partner countries, as compromising such infrastructure improves—and in some cases can demonstrate—its ability to damage infrastructure during a crisis.

- A Russian software supply chain operation in 2020, described in the cyber section of this report, demonstrates Moscow's capability and intent to target and potentially disrupt public and private organizations in the United States.

- Russia is also using cyber operations to defend against what it sees as threats to the stability of the Russian Government. In 2019, Russia attempted to hack journalists and organizations that were investigating Russian Government activity and in at least one instance leaked their information.

- Russia almost certainly considers cyber attacks an acceptable option to deter adversaries, control escalation, and prosecute conflicts.

Intelligence, Influence Operations, and Elections Influence and Interference

Russia presents one of the most serious intelligence threats to the United States, using its intelligence services and influence tools to try to divide Western alliances, preserve its influence in the post-Soviet area, and increase its sway around the world, while undermining US global standing, sowing discord inside the United States, and influencing US voters and decisionmaking. Russia will continue to advance its technical collection and surveillance capabilities and probably will share its technology and expertise with other countries, including US adversaries.

- Moscow almost certainly views US elections as an opportunity to try to undermine US global standing, sow discord inside the United States, influence US decisionmaking, and sway US voters. Moscow conducted influence operations against US elections in 2016, 2018, and 2020.

Space

Russia will remain a key space competitor, maintaining a large network of reconnaissance, communications, and navigation satellites. It will focus on integrating space services—such as communications; positioning, navigation, and timing (PNT); geolocation; and intelligence, surveillance, and reconnaissance—into its weapons and command-and-control systems.

- Russia continues to train its military space elements and field new antisatellite (ASAT) weapons to disrupt and degrade US and allied space capabilities, and it is developing, testing, and fielding an array of nondestructive and destructive counterspace weapons—including jamming and cyberspace capabilities, directed energy weapons, on-orbit capabilities, and ground-based ASAT capabilities—to target US and allied satellites.

IRANIAN PROVOCATIVE ACTIONS

Iran will present a continuing threat to US and allied interests in the region as it tries to erode US influence and support Shia populations abroad, entrench its influence and project power in neighboring states, deflect international pressure, and minimize threats to regime stability. Although Iran's deteriorating economy and poor regional reputation present obstacles to its goals, Tehran will try a range of tools—diplomacy, expanding its nuclear program, military sales and acquisitions, and proxy and partner attacks—to advance its goals. We expect that Iran will take risks that could escalate tensions and threaten US and allied interests in the coming year.

- Iran sees itself as locked in a struggle with the United States and its regional allies, whom they perceive to be focused on curtailing Iran's geopolitical influence and pursuing regime change.
- Tehran's actions will reflect its perceptions of US, Israeli, and Gulf state hostility; its ability to project force through conventional arms and proxy forces; and its desire to extract diplomatic and economic concessions from the international community.
- With regards to US interests in particular, Iran's willingness to conduct attacks probably will hinge on its perception of the United States' willingness to respond, its ability to conduct attacks without triggering direct conflict, and the prospect of jeopardizing potential US sanctions relief.
- Regime leaders probably will be reluctant to engage diplomatically in talks with the United States in the near term without sanctions or humanitarian relief or the United States rejoining the Joint Comprehensive Plan of Action (JCPOA). Iran remains committed to countering US pressure, although Tehran is also wary of becoming involved in a full-blown conflict.

Regional Involvement and Destabilizing Activities

Iran will remain a problematic actor in Iraq, which will be the key battleground for Iran's influence this year and during the next several years, and Iranian-supported Iraqi Shia militias will continue to pose the primary threat to US personnel in Iraq.

- The rise in indirect-fire and other attacks against US installations or US-associated convoys in Iraq in 2020 is largely attributed to Iran-backed Iraqi Shia militias.
- Iran will rely on its Shia militia allies and their associated political parties to work toward Iran's goals of challenging the US presence and maintaining influence in Iraqi political and security issues. Tehran continues to leverage ties to Iraqi Shia groups and leaders to circumvent US sanctions and try to force the United States to withdraw through political pressure and kinetic strikes.
- Although Tehran remains an influential external actor in Iraq, Iraqi politicians, such as Prime Minister Mustafa al-Kadhimi, will attempt to balance Baghdad's relations with Iran and the United States in an effort to avoid Iraq becoming an arena for conflict between the two countries.

Iran is determined to maintain influence in Syria.

- Iran is pursuing a permanent military presence and economic deals in Syria as the conflict winds down there. Tehran almost certainly wants these things to build its regional influence, support Hizballah, and threaten Israel.

Iran will remain a destabilizing force in Yemen, as Tehran's support to the Huthis—including supplying ballistic and cruise missiles as well as unmanned systems—poses a threat to US partners and interests, notably through strikes on Saudi Arabia.

Tehran remains a threat to Israel, both directly through its missile forces and indirectly through its support of Hizballah and other terrorist groups.

Iran will hedge its bets in Afghanistan, and its actions may threaten instability. Iran publicly backs Afghan peace talks, but it is worried about a long-term US presence in Afghanistan. As a result, Iran is building ties with both the government in Kabul and the Taliban so it can take advantage of any political outcome.

Military Capabilities

Iran's diverse military capabilities and its hybrid approach to warfare—using both conventional and unconventional capabilities—will continue to pose a threat to US and allied interests in the region for the foreseeable future.

- Iran demonstrated its conventional military strategy, which is primarily based on deterrence and the ability to retaliate against an attacker, with its launch of multiple ballistic missiles against a base housing US forces in Iraq in response to the January 2020 killing of Iranian Islamic Revolutionary Guard Corps Qods Force (IRGC-QF) Commander Qasem Soleimani. Iran has the largest ballistic missile force in the region, and despite Iran's economic challenges, Tehran will seek to improve and acquire new conventional weaponry.

- Iran's unconventional warfare operations and network of militant partners and proxies enable Tehran to advance its interests in the region, maintain strategic depth, and provide asymmetric retaliatory options.

- The IRGC-QF and its proxies will remain central to Iran's military power.

Attacks on US Interests and the Homeland

We assess that Iran remains interested in developing networks inside the United States—an objective it has pursued for more than a decade—but the greatest risk to US persons exists outside the Homeland, particularly in the Middle East and South Asia.

- Iran has threatened to retaliate against US officials for the Soleimani killing in January 2020 and attempted to conduct lethal operations in the United States previously.

- During the past several years, US law enforcement has arrested numerous individuals with connections to Iran as agents of influence or for collecting information on Iranian dissidents in the United States, and Iran's security forces have been linked to attempted assassination and kidnapping plots in Europe, the Middle East, and South Asia.

- Iran probably can most readily target US interests in the Middle East and South Asia because it has assets and proxies in the region with access to weapons and explosives.

Nuclear Breakout

We continue to assess that Iran is not currently undertaking the key nuclear weapons-development activities that we judge would be necessary to produce a nuclear device. However, following the US withdrawal from the JCPOA agreement in May 2018, Iranian officials have abandoned some of Iran's commitments and resumed some nuclear activities that exceed the JCPOA limits. If Tehran does not receive sanctions relief, Iranian officials probably will consider options ranging from further enriching uranium up to 60 percent to designing and building a new 40 Megawatt Heavy Water reactor.

- Iran has consistently cast its resumption of nuclear activities as a reversible response to the US withdrawal from the JCPOA and messaged that it would return to full compliance if the United States also fulfilled its JCPOA commitments.

Since June 2019, Iran has increased the size and enrichment level of its uranium stockpile beyond JCPOA limits. Since September 2019, Iran has ignored restrictions on advanced centrifuge research and development and restarted uranium enrichment operations at the deeply buried Fordow facility. In January, Iran began to enrich uranium up to 20 percent and started R&D with the stated intent to produce uranium metal for research reactor fuel, and in February, it produced a gram quantities of natural uranium metal in a laboratory experiment.

Cyber, Intelligence, Influence, and Election Interference

Iran's expertise and willingness to conduct aggressive cyber operations make it a significant threat to the security of US and allied networks and data. Iran has the ability to conduct attacks on critical infrastructure, as well as to conduct influence and espionage activities.

- Iran was responsible for multiple cyber attacks between April and July 2020 against Israeli water facilities that caused unspecified short-term effects, according to press reporting.

Iran is increasingly active in using cyberspace to enable influence operations—including aggressive influence operations targeting the US 2020 presidential election—and ***we expect Tehran to focus on online covert influence, such as spreading disinformation about fake threats or compromised election infrastructure and recirculating anti-US content.***

- Iran attempted to influence dynamics around the 2020 US presidential election by sending threatening messages to US voters, and Iranian cyber actors in December 2020 disseminated information about US election officials to try to undermine confidence in the US election.

NORTH KOREAN PROVOCATIVE ACTIONS

North Korean leader Kim Jong Un may take a number of aggressive and potentially destabilizing actions to reshape the regional security environment and drive wedges between the United States and its allies—up to and including the resumption of nuclear weapons and intercontinental ballistic missile (ICBM) testing.

- We assess that Kim views nuclear weapons as the ultimate deterrent against foreign intervention and believes that over time he will gain international acceptance and respect as a nuclear power. He probably does not view the current level of pressure on his regime as enough to require a fundamental change in its approach.

- Kim also aims to achieve his goals of gaining prestige, security, and acceptance as a nuclear power through conventional military modernization efforts, nuclear weapon and missile development, foreign engagement, sanctions-evasion, and cyber capabilities.

Military Capabilities

North Korea will pose an increasing threat to the United States, South Korea, and Japan as it continues to improve its conventional military capabilities, providing Kim with diverse tools to advance his political objectives or inflict heavy losses if North Korea were attacked.

- Pyongyang portrayed a growing and more diverse strategic and tactical ballistic missile force during its January 2021 and October 2020 military parades.

WMD

North Korea will be a WMD threat for the foreseeable future, because Kim remains strongly committed to the country's nuclear weapons, the country is actively engaged in ballistic missile research and development, and Pyongyang's CBW efforts persist.

- Despite announcing an end to North Korea's self-imposed moratorium on nuclear weapons and ICBM testing in December 2019, Kim thus far has not conducted long-range missile testing and has left the door open to future denuclearization talks with the United States. Kim may be considering whether to resume long-range missile or nuclear testing this year to try to force the United States to deal with him on Pyongyang's terms.

Cyber

North Korea's cyber program poses a growing espionage, theft, and attack threat.

- Pyongyang probably possesses the expertise to cause temporary, limited disruptions of some critical infrastructure networks and disrupt business networks in the United States, judging from its operations during the past decade, and it may be able to conduct operations that compromise software supply chains.

- North Korea has conducted cyber theft against financial institutions and cryptocurrency exchanges worldwide, potentially stealing hundreds of millions of dollars, probably to fund government priorities, such as its nuclear and missile programs.

TRANSNATIONAL ISSUES

COVID-19 PANDEMIC AND DISEASES

The COVID-19 pandemic has disrupted life worldwide, with far-reaching effects that extend well beyond global health to the economic, political, and security spheres. We expect COVID-19 to remain a threat to populations worldwide until vaccines and therapeutics are widely distributed. The economic and political implications of the pandemic will ripple through the world for years.

The pandemic is raising geopolitical tensions, and great powers are jockeying for advantage and influence. States are struggling to cooperate—and in some cases are undermining cooperation—to respond to the pandemic and its economic fallout, particularly as some governments turn inward and question the merits of globalization and interdependence. Some governments, such as China and Russia, are using offers of medical supplies and vaccines to try to boost their geopolitical standing.

The economic fallout from the pandemic is likely to create or worsen instability in at least a few—and perhaps many—countries, as people grow more desperate in the face of interlocking pressures that include sustained economic downturns, job losses, and disrupted supply chains. Some hard-hit developing countries are experiencing financial and humanitarian crises, increasing the risk of surges in migration, collapsed governments, or internal conflict.

- Although global trade shows signs of bouncing back from the COVID-19-induced slump, economists caution that any recovery this year could be disrupted by ongoing or expanding pandemic effects, keeping pressure on many governments to focus on internal economic stability. In April, the International Monetary Fund estimated that the global economy would grow 6 percent this year and 4.4 percent in 2022. This year's forecast is revised up 0.5 percentage points relative to the previous forecast, reflecting expectations of vaccine-powered strengthening of activity later in the year and additional policy support in a few large economies. The global growth contraction for 2020 is estimated at 3.3 percent.

- The resurgence in COVID-19 infections early this year may have an even greater economic impact as struggling businesses in hard-hit sectors such as tourism and restaurants fold and governments face increasing budget strains.

- The effects on developing countries—especially those that rely heavily on remittances, tourism, or oil exports—may be severe and longer lasting; many developing countries already have sought debt relief.

- The economic fallout from the COVID-19 pandemic, along with conflict and weather extremes, has driven food insecurity worldwide to its highest point in more than a decade, which increases the risk of instability. The number of people experiencing high levels of acute food insecurity doubled from 135 million in 2019 to about 270 million last year, and is projected to rise to 330 million by yearend.

The COVID-19 pandemic is prompting shifts in security priorities for countries around the world. As militaries face growing calls to cut budgets, gaps are emerging in UN peacekeeping operations; military training and preparedness; counterterrorism operations; and arms control monitoring, verification, and compliance. These gaps are likely to grow without a quick end to the pandemic and a rapid recovery, making managing conflict more difficult—particularly because the pandemic has not caused any diminution in the number or intensity of conflicts.

COVID-19-related disruptions to essential health services—such as vaccinations, aid delivery, and maternal and child health programs—will increase the likelihood of additional health emergencies, especially among vulnerable populations in low-income countries. As examples, the pandemic has disrupted HIV/AIDS treatments and preventative measures in Sub-Saharan Africa, as well as measles and polio vaccination campaigns in dozens of countries. World populations, including Americans, will remain vulnerable to new outbreaks of infectious diseases as risk factors persist, such as rapid and unplanned urbanization, protracted conflict and humanitarian crises, human incursions into previously unsettled land, expansion of international travel and trade, and public mistrust of government and health care workers.

CLIMATE CHANGE AND ENVIRONMENTAL DEGRADATION

We assess that the effects of a changing climate and environmental degradation will create a mix of direct and indirect threats, including risks to the economy, heightened political volatility, human displacement, and new venues for geopolitical competition that will play out during the next decade and beyond. Scientists also warn that warming air, land, and sea temperatures create more frequent and variable extreme weather events, including heat waves, droughts, and floods that directly threaten the United States and US interests, although adaptation measures could help manage the impact of these threats. The degradation and depletion of soil, water, and biodiversity resources almost certainly will threaten infrastructure, health, water, food, and security, especially in many developing countries that lack the capacity to adapt quickly to change, and increase the potential for conflict over competition for scarce natural resources.

- 2020 tied for the hottest year on record, following a decade of rising temperatures from 2010 to 2019. Arctic Sea ice minimum coverage reached its second lowest level on record in 2020, highlighting the increasing accessibility of resources and sea lanes in a region where competition is ratcheting up among the United States, China, and Russia.

- In 2020, six Atlantic storms passed a "rapid intensification threshold" because of warming temperatures, representing more damaging storms that offer less time for populations—as well as US military installations on the Gulf Coast—to evacuate or prepare.

- The 2020 storm season hit Central America particularly hard. The region already was suffering from several years of alternating drought and storms, increasing the potential for large-scale migration from the region as pandemic-related restrictions on movement ease.

- Environmental degradation from pollution and poor land management practices will continue to threaten human health and risk social unrest. Air pollution was the fourth leading risk factor for premature death globally in 2019, resulting in approximately 7 million deaths, and has been found to increase the susceptibility to and severity of COVID-19 infections. Despite temporary improvements in air quality globally in 2020 resulting from COVID-19 lockdowns, by September 2020 air pollution had returned to pre-pandemic levels.

- The threat from climate change will intensify because global energy usage and related emissions continue to increase, putting the Paris Agreement goals at risk. Even in the midst of a global pandemic that shuttered countries and significantly reduced travel, global CO_2 emissions only decreased by less than 6-percent in 2020. By December 2020, they had rebounded to previous monthly levels as countries began to reopen, an indication of how strongly emissions are coupled to economic growth.

EMERGING TECHNOLOGY

Following decades of investments and efforts by multiple countries that have increased their technological capability, US leadership in emerging technologies is increasingly challenged, primarily by China. We anticipate that with a more level playing field, new technological developments will increasingly emerge from multiple countries and with less warning.

- New technologies, rapidly diffusing around the world, put increasingly sophisticated capabilities in the hands of small groups and individuals as well as enhancing the capabilities of nation states. **While democratization of technology can be beneficial, it can also be economically, militarily, and socially destabilizing.** For this reason, advances in technologies such as computing, biotechnology, artificial intelligence, and manufacturing warrant extra attention to anticipate the trajectories of emerging technologies and understand their implications for security.

China has a goal of achieving leadership in various emerging technology fields by 2030. China stands out as the primary strategic competitor to the U.S. because it has a well-resourced and comprehensive strategy to acquire and use technology to advance its national goals, including technology transfers and intelligence gathering through a Military-Civil Fusion Policy and a National Intelligence Law requiring all Chinese entities to share technology and information with military, intelligence and security services.

- Beijing is focused on technologies it sees as critical to its military and economic future, including broad enabling technologies such as biotechnology, advanced computing, and artificial intelligence, as well as niche technical needs such as secure communications.

Moscow also views the development of advanced S&T as a national security priority and seeks to preserve its technological sovereignty. Russia is increasingly looking to talent recruitment and international scientific collaborations to advance domestic R&D efforts but resource constraints have forced it to focus indigenous R&D efforts on a few key technologies, such as military applications of AI.

CYBER

Cyber threats from nation states and their surrogates will remain acute. Foreign states use cyber operations to steal information, influence populations, and damage industry, including physical and digital critical infrastructure. Although an increasing number of countries and nonstate actors have these capabilities, we remain most concerned about Russia, China, Iran, and North Korea. Many skilled foreign cybercriminals targeting the United States maintain mutually beneficial relationships with these and other countries that offer them safe haven or benefit from their activity.

States' increasing use of cyber operations as a tool of national power, including increasing use by militaries around the world, raises the prospect of more destructive and disruptive cyber activity. As states attempt more aggressive cyber operations, they are more likely to affect civilian populations and to embolden other states that seek similar outcomes.

Authoritarian and illiberal regimes around the world will increasingly exploit digital tools to surveil their citizens, control free expression, and censor and manipulate information to maintain control over their populations. Such regimes are increasingly conducting cyber intrusions that affect citizens beyond their borders—such as hacking journalists and religious minorities or attacking tools that allow free speech online—as part of their broader efforts to surveil and influence foreign populations.

Democracies will continue to debate how to protect privacy and civil liberties as they confront domestic security threats and contend with the perception that free speech may be constrained by major technology companies. Authoritarian and illiberal regimes, meanwhile, probably will point to democracies' embrace of these tools to justify their own repressive programs at home and malign influence abroad.

During the last decade, state sponsored hackers have compromised software and IT service supply chains, helping them conduct operations—espionage, sabotage, and potentially prepositioning for warfighting.

- A Russian software supply chain operation against a US-based IT firm exposed approximately 18,000 customers worldwide, including enterprise networks across US Federal, state, and local governments; critical infrastructure entities; and other private sector organizations. The actors proceeded with follow-on activities to compromise the systems of some customers, including some US Government agencies.

FOREIGN ILLICIT DRUGS AND ORGANIZED CRIME

We expect the threat from transnational organized crime networks supplying potent illicit drugs, which annually kill tens of thousands of Americans, to remain at a critical level. The pandemic has created some challenges for traffickers, mainly due to restrictions on movement, but they have proven highly adaptable, and lethal overdoses have increased.

- Mexican traffickers dominate the smuggling of cocaine, fentanyl, heroin, marijuana, and methamphetamine into the United States. They produce heroin, marijuana, and methamphetamine in Mexico, and they obtain cocaine from South American suppliers. They almost certainly will make progress producing high-quality fentanyl through this year, using chemical precursors from Asia.

- The total number of overdose deaths increased from 2018 to 2019, and opioids—particularly fentanyl—are involved in more than half those deaths, according to the Centers for Disease Control. As of July 2020, provisional data suggests that the total number of overdose deaths have continued to rise.

- Traffickers temporarily slowed drug smuggling because of stricter controls along the US southwest border associated with the pandemic but have since resumed operations.

Transnational criminal organizations will continue to employ cyber tools to steal from US and foreign businesses and use complex financial schemes to launder illicit proceeds, undermining confidence in financial institutions.

MIGRATION

The forces driving global migration and displacement—including economic disparities and the effects of extreme weather and conflict—almost certainly will encourage migration and refugee flows, but pandemic restrictions will remain a check on cross-border movements. Migration and displacement will heighten humanitarian needs, increase the risk of political upheaval, exacerbate other health crisis risks, and aid recruitment and radicalization by militant groups—particularly as COVID-19 strains global humanitarian response mechanisms and funding.

Many refugees and internally displaced persons are unlikely to return to their homes.

The number of people being displaced within their own national borders continues to increase, further straining governments' abilities to care for their domestic populations and mitigate public discontent.

Transnational organized criminal groups exploit migrants through extortion, kidnapping, and forced labor, and facilitate migration to divert attention from their other illicit activities.

In the Western Hemisphere, the combined effects of the pandemic and hurricanes, as well as perceived changes in US immigration policy and seasonal employment opportunities in the United States, are creating the economic and physical conditions for a resurgence in US-bound migration—especially if COVID-19 infection rates in the United States decline.

Last year, mobility restrictions tied to COVID-19 initially suppressed migration from Central America to the US southwest border, but the number of migrants started to rise again in mid-2020.

High crime rates and weak job markets remain primary push factors for US-bound migration from Central America because origin countries lack the capacity to address these challenges.

Migration from the Middle East and North Africa to Europe has continued to decline since its peak in 2015, and COVID-19 travel restrictions are likely to further suppress migrant flows this year, but renewed conflicts in the Middle East could trigger more migration, and previous waves fanned nationalist sentiments in many European countries. Countries are witnessing the rise of populist politicians and parties campaigning on loss of sovereignty and identity. Some European countries are trying to balance migration and COVID-19 concerns with the need for workers to supplement their aging workforces.

GLOBAL TERRORISM

We assess that ISIS and al-Qa'ida remain the greatest Sunni terrorist threats to US interests overseas; they also seek to conduct attacks inside the United States, although sustained US and allied CT pressure has broadly degraded their capability to do so. US-based lone actors and small cells with a broad range of ideological motivations pose a greater immediate domestic threat. We see this lone-actor threat manifested both within homegrown violent extremists (HVEs), who are inspired by al-Qa'ida and ISIS, and within domestic violent extremists (DVEs), who commit terrorist acts for ideological goals stemming from domestic influences, such as racial bias and antigovernment sentiment. DVEs also are inspired by like-minded individuals and groups abroad. Lebanese Hizballah might conduct attacks against US and allied interests in response to rising tensions in the Middle East and as part of its effort to push the United States out of the region. The diffusion of the terrorist threat globally, competing priorities for many countries, and in some cases decreased Western CT assistance probably will expand opportunities for terrorists and provide them space to recover from recent setbacks.

ISIS

ISIS remains capable of waging a prolonged insurgency in Iraq and Syria and leading its global organization, despite compounding senior leadership losses. Although we have seen a decline in the number of ISIS-inspired attacks in the West since they peaked in 2017, such attacks remain a high priority for the group. ISIS-inspired attacks very likely will remain the primary ISIS threat to the US homeland this year, rather than plots operationally supported or directed by ISIS, given the logistical and security challenges the group would need to overcome to deploy and support attackers in the United States.

- ISIS will attempt to expand its insurgency in Iraq and Syria, where it has been attacking prominent local leaders, security elements, infrastructure, and reconstruction efforts.

- The appeal of ISIS's ideology almost certainly will endure, even if it appeals to a narrower audience. The group will continue to use its media to encourage global supporters to conduct attacks without direction from ISIS leadership, but ISIS's degraded media capabilities probably will hamper its ability to inspire its previous high pace of attacks and attract recruits and new supporters.

Al-Qa'ida

Al-Qa'ida's senior leadership cadre has suffered severe losses in the past few years, but remaining leaders will encourage cooperation among regional elements, continue calls for attacks against the United States and other international targets, and seek to advance plotting around the world. Al Qa'ida's regional affiliates will exploit local conflicts and ungoverned spaces to threaten US and Western interests, as well as local governments and populations abroad.

- Al-Qa'ida's affiliates in the Sahel and Somalia have made gains during the past two years, but the group experienced setbacks elsewhere, including losing key leaders or managing only limited operations in North Africa, South Asia, Syria, and Yemen.

Hizballah

We expect Hizballah, in coordination with Iran and other Iran-aligned Shia militants, to continue developing terrorist capabilities as a deterrent, as retaliatory options, and as instruments of coercion against its adversaries.

Hizballah's focus on reducing US influence in Lebanon and the Middle East has intensified following the killing of IRGC-QF Commander Qasem Soleimani. Hizballah maintains the capability to target, both directly and indirectly, US interests inside Lebanon, in the region, overseas, and—to a lesser extent—in the United States.

Racially or Ethnically Motivated Violent Extremists

DVEs motivated by a range of ideologies that are not connected to or inspired by jihadi terrorist organizations like al-Qa'ida and ISIS pose an elevated threat to the United States. This diverse set of extremists reflects an increasingly complex threat landscape, including racially or ethnically motivated threats and antigovernment or antiauthority threats.

Of these, violent extremists who espouse an often overlapping mix of white supremacist, neo-Nazi, and exclusionary cultural-nationalist beliefs have the most persistent transnational connections via often loose online communities to like-minded individuals and groups in the West. The threat from this diffuse movement has ebbed and flowed for decades but has increased since 2015.

- Violent extremists who promote the superiority of the white race have been responsible for at least 26 lethal attacks that killed more than 141 people and for dozens of disrupted plots in the West since 2015. While these extremists often see themselves as part of a broader global movement, most attacks have been carried out by individuals or small, independent cells.
- Australia, Germany, Norway, and the United Kingdom consider white racially or ethnically motivated violent extremists, including Neo-Nazi groups, to be the fastest growing terrorist threat they face.
- Both these and other DVEs, such as antigovernment or antiauthority extremists, are motivated and inspired by a mix of ideological, sociopolitical, and personal grievances against their targets, which have increasingly included large public gatherings, houses of worship, law enforcement and government facilities, and retail locations. Lone actors, who by definition are not likely to conspire with others regarding their plans, are increasingly choosing soft, familiar targets for their attacks, limiting law enforcement opportunities for detection and disruption.

CBRN

Terrorists remain interested in using chemical and biological agents in attacks against US interests and possibly the US homeland.

CONFLICTS AND INSTABILITY

Internal and interstate conflict and instability will continue to pose direct and indirect threats to US persons and interests during the next year. Competition for power and resources, ethnic strife, and ideology will drive insurgency and civil war in many countries. Interstate conflicts will also flare, ranging from border sparring, such as that between China and India, to potentially more sustained violent confrontations.

AFGHANISTAN

We assess that prospects for a peace deal will remain low during the next year. The Taliban is likely to make gains on the battlefield, and the Afghan Government will struggle to hold the Taliban at bay if the coalition withdraws support.

- Kabul continues to face setbacks on the battlefield, and the Taliban is confident it can achieve military victory.

- Afghan forces continue to secure major cities and other government strongholds, but they remain tied down in defensive missions and have struggled to hold recaptured territory or reestablish a presence in areas abandoned in 2020.

INDIA-PAKISTAN

Although a general war between India and Pakistan is unlikely, crises between the two are likely to become more intense, risking an escalatory cycle. Under the leadership of Prime Minister Narendra Modi, India is more likely than in the past to respond with military force to perceived or real Pakistani provocations, and heightened tensions raise the risk of conflict between the two nuclear-armed neighbors, with violent unrest in Kashmir or a militant attack in India being potential flashpoints.

MIDDLE EAST

The Middle East will remain a region characterized by pervasive conflicts, with active insurgencies in several countries, sparring between Iran and other countries, and persistent terrorism and protest movements sparking occasional violence. Domestic volatility will persist as popular discontent and socioeconomic grievances continue to rise, particularly as the region contends with the economic fallout from the COVID-19 pandemic and its leaders struggle to meet public expectations for political and economic reform. As a result, some states are likely to experience destabilizing conditions that may push them close to collapse. Conflicts that have simmered may flare, particularly if Russia, Turkey, and other countries intervene, increasing the risk of escalations and miscalculations.

Iraq

The Iraqi Government almost certainly will continue to struggle to fight ISIS and control Iranian-backed Shia militias. Baghdad relies on US and other external support to target ISIS leaders and cells; the group nonetheless has shown resilience as an insurgency. Iranian-backed Shia militias are likely to continue attacks against US targets, such as the February rocket attack on Irbil International Airport, to press US forces to leave if the Iraqi Government does not reach an agreement with Washington on a timetable for withdrawal. US personnel would also face danger if popular protests against government corruption and a declining economy took a more violent turn or if Baghdad became embroiled in a broader regional conflict.

Libya

The interim Government of National Unity will face enduring political, economic, and security challenges that have prevented previous governments from advancing reconciliation. Instability and the risk of renewed fighting in Libya's civil war will persist this year—despite limited political, economic, and security progress—and might spill over into broader conflict, as Libyan rivals struggle to resolve their differences and foreign actors exert influence. Egypt, Russia, the UAE, and Turkey are likely to continue financial and military support to their respective proxies. A potential flashpoint will be whether Russia and Turkey abide by the cease-fire, brokered by the UN in October 2020, which calls for the departure of foreign forces.

Syria

Conflict, economic decline, and humanitarian crises will plague Syria during the next few years, and threats to US forces will increase. President Bashar al-Asad is firmly in control of the core of Syria, but he will struggle to reestablish control over the entire country against residual insurgency, including reinforced Turkish forces, Islamic extremists, and opposition in Idlib Province. Asad will stall meaningful negotiations and rely on the support of Russia and Iran. The Kurds will face increasing Syrian regime, Russian, and Turkish pressure, especially as Kurdish economic and humanitarian conditions decline and if the United States withdraws forces. US forces in eastern Syria will face threats from Iranian and Syrian-regime-aligned groups, mostly through deniable attacks. Terrorists will try to launch attacks on the West from their safe havens in the country, and increased fighting or an economic collapse might spur another wave of migration.

ASIA

The Burmese military's February seizure of power, detention of State Counselor Aung San Suu Kyi, and declaration of a one-year state of emergency marked a break in that country's democratic transition and ushered in new societal instability and widespread popular protests amidst COVID-19-related economic strains.

LATIN AMERICA

The Western Hemisphere almost certainly will see hotspots of volatility in the coming year, to include contested elections and violent popular protests. Latin America will hold several presidential and legislative elections this year, some of which—such as Honduras and Nicaragua—are occurring amidst heavily polarized environments in which allegations of fraud probably will arise.

- Public frustration is mounting over deep economic recessions following the COVID-19 pandemic, which is also compounding public concerns about crime and widespread official corruption. Colombia, Guatemala, and Peru have witnessed protests during the pandemic.

- Already-high rates of crime and narcotics trafficking probably will increase as poverty worsens and resources for police and judiciaries shrink, potentially fueling migration attempts to the United States.

- The political and economic crisis in Venezuela will continue, sustaining the outflow of Venezuelans into the rest of the region and adding strain to governments contending with some of the highest COVID-19 infection and death rates in the world.

AFRICA

East Africa will struggle with ethnic conflict in Ethiopia, power struggles within the transitional government in Sudan, and continued instability in Somalia, while a volatile mixture of intercommunal violence and terrorism will threaten West Africa's stability. Conflicts, undergoverned spaces, the marginalization of some communities, and persistent communications connectivity are likely to fuel terrorism during the next year, particularly in the Sahel and parts of eastern and southern Africa. Throughout Sub-Saharan Africa, a string of contentious elections will elevate the risk of political instability and violence.

Senator BARRASSO. Mr. Dabbar, we need to ensure that our research does not fall into the wrong hands. Could you talk a little bit about what measures the Department of Energy has put in place to ensure that research funding and research results do not go to groups and individuals with ties to our adversaries, like China and Iran?

Mr. DABBAR. Yes, Senator.

I think it's vitally important that agencies have to have a culture and processes in place associated with when there's a technology that has both open science and classified applications. And that management, both processes and the culture of managing that where, in one point you can be talking about open science, about quantum and talking about something, you know, like neutrinos or, you know, but in the exact same instance, you're talking about quantum computing and highly important intelligence topics and know where that continuum is.

So you need to have a process in place. You need to have a culture in place so that when the technology conversation moves from open science and that's fine to invite people from all over the world and drive it forward, but then, when it starts crossing over, put those controls in place, there's a significant amount of controls that DOE has put in place that's too long to get into, but there's, a lot of that has been put into place over the last few years in regard to this FBI report and all the issues——

Senator BARRASSO. Thank you.

Mr. Chair, I know my time is out. If I could just have a couple of seconds to ask Dr. Mason about the national labs and what they're doing to safeguard that same intellectual property that emerges from your research?

Dr. MASON. Yeah, this is not a new thing for us. In fact, before joining Los Alamos I was the Director at Oak Ridge National Lab and it was actually over ten years ago that we first discovered that we had some employees who had, without disclosing it, enlisted in this so-called Thousand Talents program and we terminated their employment and that was over ten years ago. Before there was a lot of awareness about that particular approach that the Chinese government had adopted to acquiring science and technology. The reason we became aware of it is because we have a counterintelligence program. Because of the nature of what the national labs do, we do work in classified areas. We do work in export-controlled areas, you know, we have to have processes to protect that information. And it was actually our counterintelligence shop who became aware through their due diligence of this involvement.

Now, of course, they thoroughly investigated to make sure that there was no espionage and no violation of law in terms of export controls, but then at that point it fundamentally became a problem of compliance with our policies and procedures and, quite frankly, scientific ethics. No scientist wants to have their ideas stolen and no research institution should tolerate that and we did not tolerate it then and we do not tolerate it now.

The CHAIRMAN. Thank you, Senator.

Senator Heinrich.

Senator HEINRICH. Thank you, Chairman.

Dr. Mason, I want to continue on that because I think this issue of open science versus classified science and being able to manage those two in concert and deconflict those is something that is unique, you know. Because of its history, DOE has been doing that from the very start.

So, you know, I appreciate what you said about the National Science Foundation. It is an incredibly important institution in our overall R&D as a country, but do they have the infrastructure in place to be able to manage both open science and classified science in areas like quantum, like cybersecurity? Obviously that infrastructure has been built into our DOE national security labs.

Dr. MASON. Yes, certainly you're correct, it's in our history. At Los Alamos, we are very proud of the fact that our history includes significant contributions from scientists all over the world, including in the Manhattan Project where refugee scientists from Europe were key to solving many of those technical challenges. It does sometimes surprise people when they discover that Los Alamos, we have foreign nationals working in some of our programs, not in our classified programs, not in the nuclear weapons program, but we need to do the very best science in order to keep the country safe and secure and one way we do that is by engaging globally with partners who share our values and who understand that international collaboration, when it's done in a transparent way for mutual benefit, helps solve really tough problems.

And so, it is a balancing act. We have to be very attentive to when we start to cross the line on some of those dual use areas that Under Secretary Dabbar mentioned. But it's something that we have learned to do.

Senator HEINRICH. Is there really any entity in the U.S. Government that has as much expertise in managing those two things simultaneously in the interplay there as DOE through the national security labs?

Mr. Dabbar, do you have a thought on that?

Mr. DABBAR. I think DOE is actually has the most experience because there's plenty who have very open experience. NSF is one. NIH is one. At the other extreme you have the intelligence agencies of DoD and DOE sits in the middle, and I think it's the most balanced and that transition of all the entities.

Senator HEINRICH. It seems like——

Dr. PIERPOINT. May I respond as well, Senator Heinrich?

Senator HEINRICH. I am sorry, yes, absolutely.

Dr. PIERPOINT. Thank you, Senator Heinrich.

So, you know, I just want to agree with what my colleagues have said here. I think one key thing to understand is that, you know, the NSF has a very important role supporting universities and many universities have a very open concept——

Senator HEINRICH. Right.

Dr. PIERPOINT. ——and open way of approaching the work that they do and that's actually extraordinarily important for their success.

Senator HEINRICH. It is a good thing, yes.

Dr. PIERPOINT. Exactly, whereas at the Department of Energy labs there really is this unique ability to be able to conduct research in this way.

Senator HEINRICH. And what I am trying to get at in all of this, and I appreciate that additional perspective, Dr. Pierpoint, is that there are different tools for doing different parts of this infrastructure for R&D and innovation and the transfer of innovation into the private sector. And so, if we are going to invest intelligently in the whole ecosystem of that, that we have built as a country, rather than standing up or, you know, reinventing additional infrastructure when we have mission-driven centers of excellence. Whether that is in biotechnology or quantum or energy, we have built this constellation over the course of many decades. And it seems to me, rather than try to reinvent the wheel in one particular agency, we should look at where the centers of excellence are in all of those agencies, in the technologies that we have identified as particularly important for global competitiveness and we should double down where that lives, wherever it lives, across the federal research infrastructure.

Do you all agree with that type of approach?

Mr. DABBAR. It makes a lot of sense to me.

[Laughter.]

Dr. PIERPOINT. I do, and I'd like to add that I think one of the unique strengths that DOE brings to the table is that while it is not perfect, they have the best infrastructure that I know of among all agencies for partnering with the private sector. So again, when the goal is really to have impact and to support American competitiveness and the economy, I think they really have some unique resources that don't exist elsewhere.

Senator HEINRICH. Dr. Pierpoint, thank you for bringing up the contract issue. As someone who has dealt with the labs for many years, there are things we can do better. There is no question about that. We could change the culture to also make it easier to transfer, you know, appropriate technology that is not national security related, into the private sector, make that easier, but these are the centers of excellence, right now, for the things that we are arguing about regarding global competitiveness. And that is where we need to make this investment.

Dr. PIERPOINT. I agree.

The CHAIRMAN. Thank you, Senator.

Senator Lankford.

Senator LANKFORD. Chairman, thank you.

I am fascinated to be able to hear all the dialogue today and all the conversation about where things go. One of the questions here is about innovation and where things go. Ms. Ladislaw, you mentioned several times about innovation and the focus on energy innovation and what has happened with DOE already. I would be interested to be able to dig in, what we are doing policywise to be able to continue to encourage the next level of innovation, the next level of energy development and what we are doing to discourage innovation in the process, both in our policies, tax policy, investment strategy, whatever it may be. We have done a lot of investment in the past. We have more to go. What are we doing to discourage innovation? What are we doing to encourage it at this point?

Ms. LADISLAW. Thank you very much for the question.

I mean, on somewhat broad terms, my last job just released a study looking at the track record of different countries around the world and their success in being able, not only just to create innovative new technologies, but to actually deploy those technologies, manufacture those technologies. And what we're seeing is, in particular in the energy space, because there is such a transformation going on, such an interest in technologies that reduce greenhouse gas emissions, how to not only drop the cost of those technologies, but integrate them into the energy system much more quickly, think about how you do that for energy intensive industries as well.

There's a lot of focus on deployment-led innovation, right? It's not just about being able to come up with the idea. It's about being able to implement the idea, figure out how it works in the modern economy and do that quickly. I mean, one thing that we tend to, sort of, gloss over in a lot of these discussions about innovation is what is the rate and pace of the competitive challenge that we're facing? And if you look at other countries that are trying to move as quickly as possible in decarbonization, they're going to do things that don't make sense in other economic terms. You just wouldn't do this normally if you didn't want to reach those types of targets. They're going to move more quickly. They might waste money. They might have, you know, less success in some instances, but they are going to try to move more quickly, put more enabling infrastructure, more tax policy, both the supply side, investing in R&D, but also making sure that those technologies get pulled into the market quickly. And that's going to give them an edge at thinking about how you transform the energy system of today.

So I think the U.S. is not doing enough on thinking about, not just how do we create the best ideas in the world, we already do that, to a certain extent, but how do we become the people who put them into the market first, to understand what is working or not working in some of those technologies and improve on that in real time and much more quickly because I think our competitors are prepared to move more quickly than we are.

Senator LANKFORD. So are we investing too much in incumbent technologies because we put billions of dollars in some technologies that already exist and are already well developed in different tax credits and other things. The wind tax credit is one of those examples that we've done, the PTC, for years. Wind is clearly no longer a new technology on the go, but we still continue to spend billions of dollars to be able to reinforce that as well. Should we spend some of those dollars on new technologies or continue to invest in incumbent technologies?

Ms. LADISLAW. I tend to think that we need to think about new types of challenges as they apply to those types of technologies. So, for example, wind is not done innovating, right?

Senator LANKFORD. Right.

Ms. LADISLAW. There are new types of wind technologies. There's new types of solar technologies. So we need to think about how and where to spend dollars and to incentivize the improvement of technologies and their performance or their very nature, but also how do you integrate them into the grid? How do you think about distributed energy resources at a much higher scale? What does that mean for our enabling infrastructure?

Yes, we absolutely underinvest in the technologies that we need to be thinking about for the future. I try to not think about things as being incumbent technologies and therefore, you know, you shouldn't invest in them anymore. Listen, if they have a viable pathway to play in this future that we're talking about where the priority is it needs to be secure, it needs to be reliable, it needs to be sustainable, it needs to drop emissions, then we should be investing in those if we see there's a viable pathway for some of those technologies. CCUS, hydrogen, all of those types of things require much more attention than we're giving them right now.

Senator LANKFORD. Okay, let me just ask one more quick question on this as well and it's dealing with what several other folks on the dais have already talked about, that is dealing with duplication of research. Obviously, it is good to have multiple voices that are out there to be able to look at it, multiple pathways, but the security side of this is extremely important as well that when you are developing technology and resources, we are not just sharing information, but we are also not exporting information to other folks like China, that want to be able to steal that information.

How do you see the best way for us to be able to balance continued sharing of information, but also protecting the security of information to make sure that we are not keeping things in silos, but to also make sure we are not giving away what we are doing?

Mr. DABBAR. Senator, one of the things that we did at DOE—a little bit more on the details of what Senator Barrasso and Senator Heinrich talked about—was that we actually created something called a risk matrix which actually went with the Chief Technology Officers, Research Officers, of each of the different labs and we went technology by technology and we identified, you know, at the basic research level which of the areas are really open science. Okay? And there's many things, obviously energy, many areas in energy are open science and other areas and then what very specifically, let's say, battery technologies that become military grade, right? Once again, I used Quantum, there's clearly open versus extremely classified. I could go one by one. And we actually created a whole matrix. It's pretty darn thick because we went technology by technology subsets, and when we put walls in place and saying this is completely open and this is, this is going to be classified.

And actually, the labs all have this as policy right now as a part of that. That was something that we developed and it's being expanded actually, I think, at the Department last time I heard.

Senator LANKFORD. Okay, that's very helpful. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Cantwell.

Senator CANTWELL. Thank you, Mr. Chairman, and I so appreciate this discussion, actually. I think this is so healthy coming from a very big innovation state that has a national lab. We are excited about everybody being excited about the future of innovation investment. So definitely, definitely appreciate just the ongoing, continuous contributions of our national labs. If anything, I feel like it is always underestimated or appreciated or underabsorbed. So I think this larger discussion is really not about basic research, but about how do we get more translational research.

And so, I do think that is an interesting question about how prepared the labs are to play that role or not to play that role or what could we do. We had good discussion yesterday in Commerce, and a very interesting observation by one of the witnesses from the University of Washington where, basically, they brought the outside venture capital into the university and then made significant strides in the amount of tech transfer that then was enabled. And so, one of the comments came to a question about China and competition and that was, you know, "what to do?" One of the things was just to make patentable dollars available because at the university level, they are not patenting it. So basically, we are doing this great research, we are not patenting it, we go and give a big discussion somewhere, people read and hear the discussion, and then they run home and basically copy the information.

So I don't know, Mr. Dabbar, what you think about at the lab level, but certainly at the university level, it seems to me, like we need to be putting some resources in to protecting our R&D into patentable content.

Mr. DABBAR. Yes, Senator. If you don't mind, I'd like to say thank you for your comment a couple of months ago about EM and about our work for the last four years. I just wanted to say thank you for your kind comment——

Senator CANTWELL. Oh, so proud of you guys.

Mr. DABBAR. ——on the partnership there for the last few years.

Yes, no, Senator, you're exactly right. There is almost no money going into the national labs or to universities to patent and secure technology. Dollars are not appropriated for—it's basically legal work and when money comes into the big science entities, all of our, all the different agencies, money doesn't get appropriated to support, basically, legal protections associated with that. And maybe that's something to look at. That's for you to think about.

Senator CANTWELL. I was not a fan of changing this policy, the First to File. I personally think it undervalues the original inventor because, if you are just in a horse race to who can file, then you are really just accelerating a bunch of people who have the ability to file quickly.

Mr. DABBAR. Yeah.

Senator CANTWELL. And I don't really think of our lab people either at universities or at the national labs as people standing around doing the legal work on patent filing. I am not even sure they are compatible. They probably understand what needs to be patented, but that is a different kind of function. So I do think that accelerated this problem, personally. That is why I would spend some money there.

Dr. MASON. If I could offer an observation.

Dr. PIERPOINT. May I make a comment on this as well?

Senator CANTWELL. Yes, go ahead.

Dr. PIERPOINT. Okay, thank you.

No, I just wanted to say I think this is a really important discussion and it's also important to consider, not just the question of patents and how the labs might be able to, you know, to patent their technologies and potentially move them forward, but really, again, holistically, thinking about what does it look like to commercialize technologies that come from the laboratories and how do you harness the best of what the labs bring to the table with the best of what the private sector can offer——

Senator CANTWELL. Yes, so, I made my comments clear yesterday. We have to have a market-driven approach. I am not going to be for something that looks like some planned economy. And I do want the private sector because when you are really investing real capital dollars, I guarantee you will get the best technology solution. When you stand back and let government do it, I am telling you—in aerospace competition, we continue to win the day because other countries think that they are going to have a government-down approach, and it does not work. When the capital markets have to scrub what is the next best generation plane, I guarantee you, they come up with good answers.

I want to ask an important question because in the context of your discussions, energy markets, we are falling behind. So when it looks to where we are as a nation, you know, on the R&D side we are like 13th or 14th in energy R&D compared to China which ranked fourth. So, one of the things, I think, in all of this discussion, we need to think about are what are the big picture issues? Where do we, as a nation, want to be competitive? I would think energy just because it is a ginormous market we do want to be competitive in. So the question is what level of investment do we need in the R&D on the energy side to be competitive with China which seems to be making big strides in this particular area as it relates to next generation energy technologies?

We had a great hearing on nuclear just the other day and what we were doing on next generation nuclear reactors. I thought that was an important role for DOE, but I would assume there are others. Mr. Dabbar, or any of the other witnesses?

Mr. DABBAR. I would just, kind of, reinforce what Ms. Ladislaw said. One of the things I think we do well at is we do a lot of basic research well, but how we translate it is poor. And I'll give an example of something which is in process. It's actually also at PNNL which is around the Grid Storage Launchpad which is around the Energy Storage Grand Challenge which, so, is a big storage effort that was authorized under, also under the Energy Act of 2020. If you look at SunShot as a very successful example, previously, around driving down solar costs. It was very, very successful at the technology of the science and the deployment and the development of prototypes, but that was extremely successful. What was not successful was building a supply chain and manufacturing here in this country, right?

And so, with a great program it had a miss of along those lines. So one of the things that was structured as part of the Energy Storage Grand Challenge is to add that, is to take, basically, replicate SunShot from the technology and the deployment but then add on to it, it working with manufacturers and users here in this country at the same time, not wait, but at the same time so we're able to pull that all the way through from the development to the manufacturing and the supply chain, obviously, very topical. I'd recommend more of that go on, not just in storage and next generation batteries.

Senator CANTWELL. Well, thank you.

I know my time is way past so, Mr. Chairman, I look forward to working with you and Senator Barrasso on making sure that energy, you know, in any federal investment is prioritized because I think it is one of the biggest competitive challenges we face and I think the United States has a lot to contribute here. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator Cassidy.

Senator CASSIDY. Thank you all.

I apologize if I am going to ask questions which have been asked by others. I have been monitoring two other committee hearings and so, again, I apologize for any redundancy and also if I mispronounce your name, Ms. Ladislaw. I think I did okay with that.

You know, we have developing countries which need energy for their people to become more prosperous. It would be—and I think that is why we are seeing such an appetite for Chinese coal-fired plants, even though I am told they are kind of a primitive technology, because energy is needed. So I guess as I am looking at this, we have to meet that kind of steady flow of energy requirement that India and Pakistan and other countries will demand, but we want to do it in a way which does not have China building these coal-fired plants with all of the associated problems.

Now, and in our country we are going to incentivize, with a lot of carrots, a lower carbon future, but that is inherently going to be more expensive so, therefore, less exportable as a model. First let me start off with this. John Kerry has said that he does not approve of the United States building liquefied natural gas terminals and natural gas power in countries, in Africa, for example. I see that as supplanting coal-fired plants built by China with the obvious much better carbon emission profile associated with Louisiana natural gas or any other state's natural gas going over there. Do you have any thoughts about that? What benefits would occur if these coal plants from China were being replaced by natural gas plants built by the United States?

Ms. LADISLAW. Sure, thank you very much for the question.

You know, to be honest with you the way that you frame the question is why this innovation challenge is so exciting, right? I mean, I think if you look at the way in which we were able to drop the cost of renewable energy technologies like solar and PV, solar PV and wind, over the course of the last 20 years, it's nothing short of remarkable and we're doing the same thing with lithium-ion storage right now.

Senator CASSIDY. Let me ask because——

Ms. LADISLAW. I'm sorry.

Senator CASSIDY. Yes, I have limited time, if I may——

Ms. LADISLAW. Sir, yes.

Senator CASSIDY. ——because I want to go back to my question. Because I think I can take it as a given that if we are having problems balancing load between our renewables and it is going to require a country to have that sort of integration with the computer system, et cetera, that probably most are going to go to a more traditional form of energy, at least initially, to power. Yes, on the margin, renewables can be useful, but it certainly won't be 100 percent of an industrializing grid. I mean, do you reject that premise? I'm just curious.

Ms. LADISLAW. No, no, sorry, sir, I was taking too long to get to the core of your question.

Listen, I think that on a case-by-case basis, the choices for developing economies to develop their economies using the energy resources they need is very hard for any developed country to sit here and say, you can or you cannot use certain things, right? I think there are challenges to developing economies using natural gas in their electric power systems that we've seen time and again. And their familiarity with coal, the competitiveness of coal in those context is a very, sort of, is a very tricky thing.

So I think the question is how do you compete in the technologies of the future in developing economies in a way that, you know, what is the difference between what you try to sell them today versus what you are going to try and sell them down the line. There is a lot of pressure on China and India and Japan and Korea and other places not to be developing these coal-fired power generation technologies and selling them into these, you know, developing economies. I think that's going to be something you hear a lot about out of this Administration.

Senator CASSIDY. Let me stop you there because the pressure on China does not seem to be working and, indeed, when I am reading about the projects that they are developing post-COVID like 60 percent of them are all very carbon intensive. So it does seem like, if we are going to do something about that, we have to do something different than what we are doing.

Ms. LADISLAW. Absolutely.

And I think that if this is part of the U.S. trying to figure out how are we going to compete in these third markets and how do we do it in such a way that we can outcompete China. You know, we did some, a lot of studies on the Belt and Road Initiative and other investment that China are making in these other markets and one thing I'll say is one of the biggest problems is the U.S. just wasn't present in those competitions. We just weren't. We didn't have a strategy for engaging, and so I think that it's really a big part of trying to think about how to do that.

Dr. MASON. And I think this is the real driver behind why we need innovation. We are not going to tell the Third World you cannot improve your standard of living. And the fundamental difference between the U.S. or European or Japanese standard of living and a Third World standard of living is energy. If you look at the per capita energy consumption in the U.S., we are basically, if you look at it in terms of human equivalence you eat 300 calories worth of food a day, every man, woman and child in the U.S. has the energy equivalent of 100 servants in the form of transportation and light and heating and cooling and the rest of the world wants that and we have to innovate in order to be able to provide it to them at an affordable way with U.S.-made products and services that does not cause intractable harm to the environment.

And if we can do that, then not only will the standards of living rise around the world, but it will drive our economic development as we sell those products and services into those markets.

Senator CASSIDY. Thank you, Dr. Mason. I totally agree with you.

I will yield back, Mr. Chair, thank you.

The CHAIRMAN. Thank you, Senator.

Senator Hirono.

Senator HIRONO. Thank you, Mr. Chairman.

This is for the panel. The National Climate Assessment released in 2018 estimated $500 billion in lost economic output annually by the year 2100 due to global warming at or above two degrees Celsius. The National Climate Assessment also identified the damage to the health of Americans from extreme weather, the easier spread of infectious diseases, and reduced food safety, among other consequences and we are putting the health and well-being of the public at greater risk if we do not accelerate adoption and innovation in zero carbon energy sources. Now the panel today is focused on how to foster U.S. technology leadership and President Biden has laid out his vision of how investing in new clean energy technologies will help build the middle class in America and expand economic opportunity.

For the panel, if we can spur a greater U.S. leadership in clean energy technology, how big is the global marketplace for clean energy going to be and are we poised to take advantage of that market? Perhaps we can start with Ms. Ladislaw.

Ms. LADISLAW. Yes, thank you for the question and for thinking about the consequences of not actually taking this big opportunity to lead in these technologies.

I cited in the testimony, $2.6 trillion annually in the sustainable development scenario and that doesn't get to net zero by 2050. So when you think about the sheer size of a market that's trying to transform the underpinning of the global economy to something that's net zero, it's hard to put a figure that large in place. And so, there is a huge opportunity. There's also a lot that can go wrong. And so, we need to think carefully about how we do this. I don't particularly think that the United States is positioned as aggressively as it could be not only to make that transition, but also to be able to be very competitive in the context of that transition.

Dr. MASON. I think there's another way to think about this. Think about the last great energy transition that happened at the end of the 19th century as you saw petroleum and electrification and then ask yourself what names and companies are associated with that? And what you think about is Standard Oil and you think about Edison and you think about Westinghouse. The U.S. drove that energy transition and the U.S. economy benefited from that for decades, for a century after that. And so, its companies that represent a huge fraction of our gross domestic product and not only that, it's that same energy engine that, you know, won the Second World War.

So that gives you an idea of the scale of the consequences associated with an energy transition. And you have to ask, is the next Edison, is the next Westinghouse, is the next Standard Oil going to be American?

Senator HIRONO. That is the question.

Mr. DABBAR. I would say, Senator Hirono, that there are a great amount of very exciting technologies that are all being worked on right now that we need to figure out how we're going to manufacture, just like we have in the past. We're, right now as a country, very good at oil field services, at steam turbines and gas turbines, in terms of manufacturing, but there's whole swaths of areas that we don't—in PV, in solar and wind.

Senator HIRONO. Yes.

Mr. DABBAR. And the question is, you know, how do we drive the next, right? How do we—next generation chemistry, manufacturing and supply chain. We should be very much focused on where the puck is going—to talk to, to use the Gretzky reference—and invest in those so that we start manufacturing those like we manufacture other things well.

Senator HIRONO. Yes, I think if we are looking ahead, we are going to be looking to non-fossil fuel kinds of energy sources and so as a country we can be a leader there, but I don't think we are particularly positioned in that regard.

Did any of the other—go ahead.

Dr. PIERPOINT. Oh, thank you.

If I could just make one quick comment which is that, you know, I agree. And Senator Hirono, I think your question is really quite apt because it's important to recognize that this is a very complex set of systems that we need to address simultaneously. So in order to reap the economic benefits here, absolutely we need to invest in innovation and really strengthen those innovation ecosystems within the United States. We also need to be very proactive about setting our posture to take advantage of these global markets, and as Ms. Ladislaw laid out, I think there's more we need to do there.

And then, you know, to go back to Senator Lankford's questions as well, there are other pieces to this too. So, for example, it's really important to set the policies that make it clear to the private sector what demand is going to look like. What are the standards to which we are aiming? You know, what exactly is the structure of our business models and our markets? Because as much clarity as we can possibly get on that will actually really encourage the private sector to step up and take a much stronger role in innovating and commercializing. And when you bring all these things together, that's where we can be most powerful as a nation and ultimately reaping the benefits of the economic opportunities here.

Senator HIRONO. I think one of the things that happens is if you put out a clean energy goal and standards, as Hawaii has done, then you do invite the private sector to come forward and provide those kinds of alternatives. And that is why, you know, I am for these national kinds of standards that will encourage the private sector to step up.

Thank you.

The CHAIRMAN. Thank you, Senator.

Senator King.

Senator KING. Thank you, Mr. Chairman.

First, I want to follow up on Senator Cassidy's comments about natural gas. I have been an advocate of replacing oil and coal with natural gas, but it is important to realize that unless we control the methane that is released in the extraction of natural gas, its carbon benefit virtually disappears. So there is a CRA that is going to be on the Floor in the next week or so on that subject, and I think it is a case where it is low-hanging fruit. It is very cost-effective and the methane problem is one that can be dealt with, but if we don't deal with it, as I say, it virtually eliminates the environmental benefits of natural gas.

Let me, let me go to Mr. Dabbar. I want to flip the discussion. We have been talking a lot about protecting American innovation and taking advantage of the market opportunities, but many of these challenges that we have—battery storage, the new generation of nuclear electrical generation, CCUS, doing something about plastics in the ocean—are global problems. How about a global or a more international-focused joint venture, if you will, at least with our allies so that we are not all chasing the same subject in a less efficient way? For example, I was talking with some legislators in Japan last week, very interested in some joint research projects on energy. Talk to me about the possibility of explicit joint enterprise on some of these global energy problems.

Mr. DABBAR. Yeah, Senator King.

You know, from my personal experience of having to reach out to the Japanese, had Japanese conversations, European, you know, discussions. I apologize—I have to say something nice about America. We actually do a really good job at the national labs compared to, if you look at, is there a NETL in Europe? No. Is there an NREL in Europe? No.

And so, it's a bit hard, actually, to find, you know, the exact points overseas as you—this is actually easier in the United States to do that. I am a big supporter of the Japanese, who have been trying to come, have put together a program and are trying to identify which technologies to go after and I personally tried to reach out to them and say let's try to do something together. Let's pick off different items. Same thing with Canada. I would recommend trying to figure out a way, actually, how to formalize that, how to actually draw in, you know, Canada or Japan or the EU and do that.

Senator KING. That is what I am suggesting is some formalization of a process just to take advantage of the potential benefit of scale of research.

Let me change the subject a little bit. It strikes me that one of the comments that has come through today is we have great research but the nexus between research and commercialization in this country is not all that it might be. I think you said, Mr. Dabbar, you used the phrase, how we transfer is poor. How do we deal with that problem? Because research doesn't help us unless it leads to actual implementation. That is why R&D has the D part.

Mr. DABBAR. Well, yes, Senator. I think that it's actually much lower cost in terms of appropriations, but I think it's actually vitally important to invest, even further into the commercialization efforts at DOE, but also at the universities and whatever happens with a bigger innovation bill. I think resources to reinforce those particular areas is vitally important because, once again, as Ms. Ladislaw said, you know, we've got plenty of great ideas. We've got plenty of discovery. But I do think setting up even further efforts into that, on top of the good things that have been done for the last ten years on that, I think, is actually a great, great use of dollar.

Senator KING. I think we have to realize that there may be misses, some things are not going to work. Gretzky has already been quoted once. My favorite Gretzky quote is, "I miss 100 percent of the shots I don't take." So we have to take some risk on some of these developments.

Ms. Pierpoint.

Dr. PIERPOINT. Senator King?

Senator KING. Yes, go ahead, please.

Dr. PIERPOINT. I was just going to say I think that's a really great question and you know, again, I think coming from my position, you know, in a, where I was working on private sector R&D and very much working with the Department of Energy, I agree the gap is still really big and again, I think one of the challenges is that the gap does not look the same for every technology, even within energy. It looks different among different kinds of energy technologies, the particular barriers to moving things into the private sector are not always the same.

And so, I think it's really important that the Department of Energy continues to experiment with new kinds of tools in its tool kit to help improve the way that this transfer works. And again, sort of a really, you know, deep focus on this and a holistic transfer of the paradigm to thinking about technology impact and not just about thinking about this as a hand-off to the private sector is key. I think it's about ongoing partnering. It's about ensuring that the bureaucratic processes match with things that the private sector can actually work with and it's about really ensuring that we're thinking about holistic business-ready solution, even at the beginnings of thinking about R&D and deployment and development of new technologies.

Senator KING. Well, I am out of time, but you have a unique set of experiences in the different places where you have worked and I would like to give you some homework. If you would give to the Committee some written comments on how to improve that transfer process from your perspective, I think that would be very helpful to us as we look toward future legislation in this area.

Thank you very much, Mr. Chairman. I yield back.

Dr. PIERPOINT. Absolutely.

The CHAIRMAN. Thank you, Senator.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman, and thank you to our witnesses this morning. Good to see some folks that have been back before the Committee on multiple occasions. Good to see you, Mr. Dabbar.

I have spent my week focused on the Arctic. The past two mornings I have been engaged as part of the standing committee on Arctic Parliamentarians. So I have been thinking about the Arctic, and I have been thinking about our energy challenges. I have been thinking about our climate-related challenges in the Arctic, so I appreciate Senator King's comment there about international collaboration. What more can we be doing? We certainly discussed that from an economic development perspective, but also from an environmental stewardship perspective.

Mr. Dabbar, I will direct my first question or perhaps observation to you. We have reauthorized the Arctic Energy Office. This is good. We want to get a few more folks up there and, actually, really on the ground, but we have also developed a pretty great partnership, I think, with NREL, the National Renewable Energy Lab, and our Cold Climate Housing Research Center. Again, some might say, well, that's Alaska-specific. It is absolutely not. It is not only Arctic-specific, but recognizing that when you can make advances in housing in extreme environments, you can do it in the cold, you can do it in the not so cold. So we recognize the benefits there, but any comments in terms of, based on your perspective, what more DOE can be doing to build out these best practices, these collaborations with our Arctic neighbors?

Mr. DABBAR. Yeah. Senator, I think as we talked about before, I think the use of, to use the term test beds, for different and new technologies is vitally important. And it is really important when there's collaborators who could share what the effort and bring other ideas and other money so you can, you know, kind of bring, bring together scale, who have similar problems. And I think that American leadership is really important here where we still are the biggest country in the world in most aspects. And I think reaching out to the likes of Canada and others who have very similar issues with their local communities and different applications will leverage, I'm even going to use a banking term here, we can leverage the dollars that are spent here by the American people because other people will be contributing. And there's many programs that are very successful because we're able to do a lot more together with that leverage and also more test beds.

So I'd very much advocate for entering into really formal, more formal conversations. It's been harder to do it informally. And so, I think trying to figure out how to do it formally would be a great idea of how to do that.

Senator MURKOWSKI. Let me shift gears a little bit here, and this will be directed to you, Dr. Mason, at Los Alamos.

Talking a lot about what we are going to do to move to this renewable energy economy, what that is going to mean. We talk a lot about our supply chain vulnerability. We have really seen that spotlight shown in a COVID-related world when it comes to the medical side, but we also know that when it comes to energy, if we don't have these critical minerals, we are at a competitive disadvantage. We cannot be in a position where we rely on China. We cannot be in a position where we are relying on other countries who have lower environmental standards and lower standards when it comes to human rights and worker safety.

How we are able to access our resources, our critical minerals, and do so in a way that acknowledges the environmental stewardship that must come with it, but also in a way that we are looking to greatly reduce the emissions? I would ask if you can share with me anything that our national labs are doing, whether it is through technology development or investigating new approaches to production that will help support more responsible development of our domestic mineral resources. Part of the conversation that we had yesterday, I was reminded that I visited a site in Sweden—Kiruna, Sweden—as part of the last Arctic Council meeting, several Arctic

Councils ago, but the LKAB mine there is working toward getting themselves entirely removed from the fossil emissions as a significant mine there. I don't know whether our labs are looking at any of these technologies that might help advance us when it comes to accessing our critical minerals?

Dr. MASON. Yeah, that is actually a very active area. It certainly, the general issue of supply chain vulnerabilities is one that's very much in our awareness in the NNSA labs because, of course, we have responsibilities in the nuclear deterrent that have some of those supply chain vulnerabilities. And oftentimes, it does come down to access to very specific materials that have physical, chemical properties that make them well suited to certain applications. It turns out that in general, it's not that the U.S. does not have those minerals. We have them. But we have not been actively exploiting them for some time and in many cases, and in particular, China has been very sophisticated in its approach to, you know, leveraging their control to the current supply chain to their economic advantage.

So some of the activities at the labs include looking at some of the chemical processing in order to come up with more environmentally acceptable ways of accessing those materials that may be present in, you know, small quantities. And part of the reason that the U.S. got out of that business was because of the environmental impacts of the processing. So alternative processing technologies and chemical separations is a core competency for many of the DOE labs. There has also been work looking at alternatives. Maybe there is a smarter, better way to do it that does not give that choke hold to others in terms of the supply chain. So, there's work on alternatives. There's actually a thing called the Critical Materials Institute which is a consortium of DOE labs—Oak Ridge is involved, Ames Lab, Idaho—as well as academic researchers and industry partners that, in addition, are looking at things like recycling. You know, there's a lot of critical materials that are tossed into the trash on a pretty short time scale because they're high-tech components that may have, you know, pretty short obsolescence times. And so, if we can begin to recycle some of the Samarium, then we don't have to rely on those supply chains. And it's material science, it's chemistry, it's chemical separation. You know, these are areas that are part of the tool kit at the Department of Energy.

Senator MURKOWSKI. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you. Thank you for this great conversation today.

One of the areas I want to focus on are technology standards. And this is for the panel.

I know one area we must address as we look at global competition over new technology is the standard-setting process, specifically, what I have seen as China has established goals to set global standards for emerging technologies like 5G, internet, the Internet of Things, artificial intelligence, on and on and on. So I am curious from the panel, can you discuss the importance of the U.S. involvement in standard setting for this new technology and what steps we can take to ensure that we continue to lead the global standard-setting process? And if you would, I would appreciate, let's start with Dr. Mason.

Dr. MASON. Well, I think one of the most important things in the setting of standards is that when you invent something, you have a pretty strong say in how those standards evolved. And so, being present at birth is, I think, a key component to having a voice in that. And of course, it does become important because, you know, the world economy needs those standards to function and if you're well positioned at the beginning of the discussion then you are going to be well positioned at the end of the discussion when it turns into shipped products and so forth. And so, it is a, maybe an underappreciated role that gets played.

Of course, in terms of standard setting, the Department of Energy's primary standards role is around energy efficiency standards and that can be an important one, but it's broader than that as well.

Senator CORTEZ MASTO. Mr. Dabbar, please.

Mr. DABBAR. Senator, I would step one step further down from the chain that Dr. Mason just mentioned which is it's not only important to be at the birth of the technology, is that when we roll out that technology and start deploying it, that there's an aggressive and I think we need to have it more aggressive than we have in the recent past given what China's definitely doing this, is as they start deploying the technology into the commercial use that the federal system advocate with the private sector on the rollout of the deployment of those technologies, that that sets the standard for the rest of the world because we're leading the deployment as well as the discovery.

Senator CORTEZ MASTO. I agree and I think it is sometimes overlooked, but it is so important for us to address the global standards role here. I know we are all focused on the research and getting out ahead of the technology and making sure we are competitive and there is an advantage, but we cannot forget that there are, when we look at some of this technology, standards that are going to be set. If we don't lead, as the United States, others will lead for us and that will have an impact, really, on not just implementation but competition as well.

And so, I am curious, anybody else have any comments with respect to this?

Dr. PIERPOINT. Just one quick additional note which is, I think is, again, a very important and apt discussion and just to reinforce that it's not just about being able to interconnect which obviously has implications for competitiveness, but standards go far beyond that into things like safety. And where we see this playing out very importantly is in the nuclear sector. We want, obviously, for our nuclear plants to be competitive, but globally, we also really need them to be safe, particularly because an accident anywhere has ramifications for our own country.

So I think, you know, this is a really, really, critical piece of the discussion that underpins competitiveness and innovation as well as a lot of other areas that are of extreme importance.

Senator CORTEZ MASTO. Thank you. And I could not agree more. Safety, security, cybersecurity, privacy, I mean, it is all wrapped into this new technology and we should be really leading in this space. Thank you for that.

I only have a minute, but Dr. Mason, in your written testimony you stated that if we are to compete for the leadership role in the future, the U.S. must revitalize its physical and human capital infrastructure and have a coordinated approach between the many agencies and institutions and private industry that are currently working in key emerging technology areas. I am curious to hear more about your thoughts on the current status of the U.S. workforce when it comes to RD&D for new technologies. Are we prepared? Do we have the workforce? And what more can we do at a federal level to incentivize?

Dr. MASON. Well, just to, you know, give you some numbers. We are, at Los Alamos, in the middle, actually, of a fairly significant turnover in our laboratory staff. We have—we've been hiring about 1,000 people a year, in fact, more like 1,200 people a year in recent years. We still have a large number of our staff who are retirement eligible and so, this is going to continue for the next several years. I am very pleased with the caliber of the people that we're attracting, their enthusiasm for our mission and their technical skills. So I think we're, we are doing well in that regard, but quite frankly, it's still the pacing element for us is the rate at which we can attract, recruit and retain the very best.

The primary way we do that is first and foremost, the compelling nature of our mission and secondly, the incredible suite of tools and capabilities that we bring to bear. This is something that is attractive to graduates across a range of disciplines and I think our greatest challenge is that the infrastructure that we're bringing people into is, maybe, somewhat less encouraging than the excitement of our mission. And so, we've got some work to do there because it is difficult to bring people into a space that was maybe state-of-the-art in the '50s and '60s, but has been left behind since then. So that's probably our biggest struggle is offering people that kind of modern 21st century research environment. We do it in some areas, not so much in others.

But the final point that I'd like to make in this topic is that, particularly as a primarily physical sciences-based institution, although we do lots of biological sciences and other areas, we're primarily physical sciences and engineering. And as an institution that's focused on national security, it's very important that we are able to hire U.S. citizens with that training. And as we look at the output of graduate schools in physical sciences and engineering, that's an area where, I think, we maybe could do better. We are not educating enough of our citizens. And while we certainly are eager to hire the best and the brightest from around the world for many of our mission areas, that's really not an option. And so, things that we can do to incentivize students thinking about what their career options may be to look to those disciplines so that we have more of our own that are getting those advanced degrees would really be helpful.

Senator CORTEZ MASTO. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Now we have Senator Kelly. No, I'm sorry. I am so sorry, Senator. I have Senator Hoeven. I see where he snuck in.

Senator Hoeven.

Senator HOEVEN. Thank you, Mr. Chairman. I appreciate it.

For Mr. Dabbar, as I think you are aware, the EERC (Energy Environmental Research Center) at the University of North Dakota, and the National Energy Technology Laboratory at DOE, they have a long history of collaborating on fossil energy research and continue to work together today on what I call "cracking the code on CCUS technology." So tell me, do you believe that the widespread deployment of CCUS technologies is a key solution to addressing grid reliability and affordability while reducing emissions?

Mr. DABBAR. Senator Hoeven, clearly having baseload power that has flexibility has value and natural gas is going to be very important to have those characteristics since solar and wind don't have right now and even batteries. And so, being able to have carbon capture is clearly critical. I've seen new technologies for natural gas turbines that will have near zero emissions and that's a technology that may not come to play, but it's possible and cost-effective. And so further investment is not only critical, it's actually really possible to turn out.

And I would like to make a space reference here that I think there's like the Star Trek trifecta, as I like to think about what's going on in terms of science. The teleportation, the tricorder and the replicator are all actually reasonably possible to do right now. And if you think about the replicator, the chemistry stream that carbon capture is going to be a part of, the possibility of taking non-emitting power, whether that's nuclear or fusion or wind or solar, making hydrogen, taking carbon capture and making renewable natural gas as negative carbon and then taking that renewable natural gas and turning into monomers and polymers, turning it into plastics and turning it into this right here, is completely possible. And if you ask anyone on the chemistry string, that's completely possible, what I just described, where you could turn power into this, and carbon capture is an important part.

Now, it's chemically possible today, but the cost to make power into this, into this right now, is very, is very expensive. But it's completely possible. And an important part of making non emitting power into this or into a knee, a knee replacement, will be carbon capture.

Senator HOEVEN. So talk a little bit then about DOE's strategic capability to make that happen, to truly help us deploy CCUS in a commercial way.

Dr. PIERPOINT. Yeah, I have a quick comment to make on this topic. I think the national labs are absolutely vital to this effort. I agree with what Mr. Dabbar said that this is extraordinarily important for our future to be able to harness these technologies and across the national labs they're working on a range of approaches and ideas that could contribute to carbon capture. One with which I'm very familiar is Lawrence Livermore National Lab and its Carbon Capture Initiative. They are not only working on a range of possible technologies and approaches to do carbon capture, but they've also brought in a panel of folks designed to help them to achieve impact. So this is people from the commercial sector who can really help them design their research in a way that is going to lead very rapidly to good outcomes, and I think that's a great model for exactly what we need in this arena.

Senator HOEVEN. Dr. Pierpoint, you would say that it is very important that the Department of Energy, as well as the national labs, get on board and help us commercialize these CCUS technologies?

Dr. PIERPOINT. I do.

Senator HOEVEN. Is that your statement?

Dr. PIERPOINT. I do.

Senator HOEVEN. And you think they have the ability to do that?

Dr. PIERPOINT. I think so. Again, I think there's a lot of work that needs to be done to really ensure that there's a strong connection between the R&D activities and the labs and what the private sector is able to scale and commercialize, but I think there's some good infrastructure to build on in that regard.

Senator HOEVEN. I have worked to help secure funding for the equipment that needs to be added to these plants and so forth, loan guarantees because the companies, obviously, will have to invest to do it, as well as tax credits as incentivizing it. Are there other things? I mean, are those things helpful and what else do you think we can do to make it happen?

Dr. PIERPOINT. Yeah, I think there are a couple of opportunities. Again, you know, this notion of really strongly partnering the private sector with the national labs and their work and doing so fairly early in the process so that the work that's being done at the national labs already starts with a clear line of sight for commercial value and commercialized ability. I think that's important. And another key piece is just improving the contracting mechanism so that it becomes easier for the private sector to work with DOE on these opportunities. Shortening the length of time for negotiations is a really key piece of that.

Senator HOEVEN. Thank you. I appreciate it very much.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

And now, Senator Kelly.

Senator KELLY. Thank you, Mr. Chairman.

As a nation, we have been a leader in R&D and energy innovation for a better part of a century and Mr. Dabbar, you mentioned taking natural gas and turning it into this, it is pretty incredible. When my wife, Gabby, Congresswoman Gabby Giffords, served on the Armed Services Committee in the House, the Naval Research Lab presented her with a vial of seawater and a vial of jet fuel. The jet fuel was made from the carbon out of the air and seawater, incredible technology. Now it takes a lot of energy to do that. It also takes a lot of computing power to figure this stuff out. How do we do that?

Dr. Mason, I know you at—Los Alamos is just in the process of receiving a new supercomputer that is going to be delivered in 2023. Mr. Dabbar is working on quantum computing. I mean, these are systems and architectures that we need to remain the best innovators in the world. I am concerned that we have gone from spending 70 percent of the world's R&D budget to now we are down to 30 percent. We have problems with access to semiconductor chips. The chips that go in the computer system that you are receiving in 2023, which, I understand, comes from a British company, I think ARM Holdings, that is going to be acquired by a U.S. company. It is very positive. We are currently working on the appropriations part of the CHIPS Act to bring semiconductor manufacturing back to the U.S. to build the five-nanometer chip here on U.S. soil. And then, the first three-nanometer and, hopefully, one-nanometer chips to allow us to do things like, you know, figure stuff out like this.

I want to hear from any of you really, Dr. Mason, but anybody on their thoughts. We are at a critical part, and I know I took up most of the time here. We have to make some decisions based on R&D in the next generation chips but also getting back to manufacturing and have to make some hard decisions about how we are going to appropriate that money. I am interested in hearing from you what that balance should be.

Dr. MASON. So, you know, maybe I can start out, just, you know, the particular area you're highlighting there, high-performance computing, is one that I think is truly critical. We use it as part of the annual certification for our nuclear stockpile. I don't think there's a more critical role than that.

As you mentioned, we've just announced our plans for the next generation machine. We're already starting to look beyond in Exascale at what does that future look like. High performance computing is one area where we are no longer alone. It used to be that the U.S. dominated that field scientifically, also dominated the field in terms of manufacturing, supply chain, all these other things and, you know, certainly, the Chinese are right there with us in terms of competition. The Europeans are investing, the Japanese are investing, and the reason they're doing it is because of the tremendous power that it brings to solving the sorts of problems that you talked about.

It's interesting, the last time I was in China I had a conversation with the director of one of their computing institutes and, you know, they were justifiably proud of the fact that they had begun fielding number one computers. But he made a comment, he said, you know, when we got the number one computer, we had a big party. We drank a lot of champagne and we woke up the next day with a hangover. And I said, what do you mean? And he said, well, what we're finding is we're not getting the scientific output when we benchmark ourselves against the U.S. labs. And the reason was because, you know, with money you can get the computer, but in order to really get the utility out of it, the ability to, you know, model those chemical reactions or, you know, the performance of a nuclear weapon, you also need to bring together a whole system of people who understand that science deeply.

And that's something that we've been quite successful at and, in fact, the Chinese have figured this out, it's one reason they've got this big push to build these comprehensive national labs because they recognize if they're going to leverage the full economic benefit, they need to domestically manufacture the chips and they have made that requirement for their new machines that they're building. They recognize it's going to cost them more, but they're using it to drive their industrial development. And you also need to have the capabilities to use those machines in the scientific areas and they're investing in that as well. My own conclusion is this is not an area where we should willingly secede our leadership and that means we need to continue to invest, not just in the hardware, but also in the people and the capabilities that goes along with it.

The good news is that we have been good at that up to this point, but as I said, we're no longer alone. And one thing that I think China has come to realize over the past couple of years is they do not want their economy to be vulnerable to the U.S. turning off access. They've been concerned, obviously, with the Huawei situation about the fact that they had components of their economy that were, you know, in some sense had supply chain vulnerabilities on our side. And I think we also need to be in a position where we're protecting our advantage and don't allow ourselves to become hostage to others in this area because it's critical, both economically and also in terms of our national security.

Senator KELLY. Thank you, Doctor.

The CHAIRMAN. Senator Hickenlooper.

Senator HICKENLOOPER. Dr. Pierpoint, I cannot tell you how excited I have been, Dr. Mason and all of you, but this discussion is right up in my wheelhouse. I did some of my research when I was getting a Masters in Geology through the Jet Propulsion Laboratory and through Los Alamos and some of the technologies that went through there. I am aware of the broad range of science that all of your organizations and institutions that you represent have done.

Let me narrow it down a little bit. Dr. Pierpoint, in your testimony, you highlighted the need for DOE to foster, you know, not just innovation but entrepreneurship as well and you talked a little bit about that this morning to help connect those doing the more basic science with those more focused on commercialization to bring good ideas to the market. What does Congress need to do to incentivize and motivate those efforts?

Dr. PIERPOINT. Thanks so much for the question.

I think you're absolutely right that, again, one of the assets that the United States brings when it comes to innovation and competitiveness is really an unparalleled entrepreneurial ecosystem. And I think it's really critical to, you know, innovation and really to ultimately the economy whether you're talking about big companies or small to be able to partner with those companies, to be able to work with the Department of Energy. So I think it's really important for DOE, as DOE thinks about the best ways to foster technology impact, to think not just about the big companies and their resources and abilities, but understand that things look very different from a small startup from an entrepreneurial endeavor. And I think there are a lot of programs, ARPA-E is chief among them, that do a great job of partnering with startups, and I think the rest of DOE is starting to really do that well also.

So again, one really important factor is as we try to foster partnerships, DOE cost shares can sometimes be helpful in the sense that they require companies to have some skin in the game so they really get deeply involved in a project. But providing cost share is not always possible for startups who tend to be operating on a shoestring. So I think recognizing that there needs to be a set of tools for partnering that allows for some flexibility and that really makes it clear to startups what's out there and what's possible is totally important.

I think another thing is recognizing that the DOE and the labs bring an incredible set of assets to the table that can be harnessed for technology development and commercialization, but sometimes it's hard to know where those assets are and how to access them. And again, I think more needs to be done to make it really clear what DOE has available and to make those resources very easily accessible to every kind of company that can bring to bear in the commercialization fight. And again, a really great example of this is the gateway for advanced innovation, accelerated innovation in nuclear gain which DOE has done in partnership with Idaho National Laboratory.

Senator HICKENLOOPER. Yes, and I love the partnership approach that we see so often within those organizations and institutions at DOE. Again, as a science lover, it really is such an exciting moment to be in Washington and to be doing the kind of work we are all doing.

It is not just climate change and it is not just the issues around the natural, the life sciences, but it is our national security. Dr. Mason, in your testimony you talked a little bit about, and we talked about it this morning, the federal investments in issues that are directly affected by national security, obviously in relationship to China, that have come up several times this morning. But there are other countries getting ahead of us as well on issues, in areas like artificial intelligence and 5G and quantum computing, and they all have national security implications and economic security implications. How do we protect the investments we have made and what needs to be done to improve our innovation in these areas? What does Congress need to do?

Dr. MASON. Yeah, I think this question of the international landscape and how we work internationally is a really critical one and from my point of view, you have to think both in terms of defense and offense. The defense side is the recognition that there are, and you're correct, it's not just China, there are other countries that are aggressively seeking to develop and exploit these technologies and, in some cases, take advantage of what has been our prior approach to international collaboration and an open society to outright steal some of our ideas. And we ought to be working on a defensive side to reduce that risk of loss, reduce that risk of theft.

But I think if all we do is build up the walls higher so that we lose less, we're missing out on the other side of the equation which is the offense side of the equation. There is tremendous value to be gained by international collaboration and cooperation on tough problems with partners who share our values and commitment to, you know, transparency and mutual benefits. So at the same time that we need to work to safeguard our ideas and safeguard our intellectual properties against theft, I think we also ought to be seeking out like-minded partners and doubling down on international collaboration. I know in the area of national security we have a longstanding collaboration between the U.S. and the U.K. on the nuclear deterrent. You could not find a more sensitive area of our national security, but under the auspices of the mutual defense agreement, we work very closely with our British colleagues and both countries benefit.

So even in the most sensitive areas, you can, with careful selection of the problems you work on and careful selection of your partners, harness the benefit of bringing more minds to bear on the problem. And I think we need to pursue both tracks. We need to protect our information from those who would seek to undermine us and double down on collaboration with allies and partners who can help us solve really tough problems, whether it's in energy, artificial intelligence, you know, even areas like quantum which are very, very sensitive. You know, there are five ICE countries that we share our most sensitive intelligence information with and some of them are absolutely frontline research in quantum computing. And why would we not want to work with our British or Canadian or Australian colleagues in those areas?

Mr. DABBAR. The one recommendation that I would make is as you draft a new piece of innovation legislation, is to think about the very successful aspect of the National Quantum Initiative where you mandated that we had to include the private sector concurrently with that R&D. And by just that sheer fact of this Committee including that term in the National Quantum Initiative and when we bid out the R&D centers, the five R&D centers, there are 69 entities in the five R&D centers around the country that were bid out as a result of this Committee's action. And within the 69 entities, not only are there big universities and labs, but Microsoft is in it, Applied Materials, IBM, Rigetti, even Goldman Sachs is in a DOE Quantum Research Center and they're all looking at, as R&D is being developed concurrently, as to how do you deploy it.

Now, my best example of this is the internet. The internet was first started up in 1969 by DARPA, doing the four initial nodes and then NSF went ahead and started funding it at other universities and DOE and others, but it took 20 years from the first modem to the internet. And I would argue, that's too long and that's because the private sector was not included in the internet on day one rather than year 20.

Senator HICKENLOOPER. You could also argue that the internet was not designed to be defended which is something we deal with every day. Anyway, I am way over time.

Chairman Manchin, thank you so much. This has, I think, been the most illuminating session in my 100 days, 107 days in the Senate, and I want to commend you for helping put this together and I want to thank everybody on this panel. It is just tremendously exciting to hear these discussions and to see how much we are going to get done in the near future.

The CHAIRMAN. Thank you, Senator. We appreciate that.

Senator Barrasso.

Senator BARRASSO. Well, thanks so much, Mr. Chairman, and I would like to, along with Senator Hickenlooper, thank you for putting this Committee conference together. I mean, this is terrific. Great panelists. Great discussion. Very, very important and I think in a bipartisan way we have all learned a lot and, hopefully, the nation has as well.

I just have one last question for Mr. Dabbar. First, I wanted to introduce into the record an article from the New York Times. It was a front-page article from a way back. It was headlined, "In F.B.I. Sights, Stolen Research Flowing to China." The article quotes Dr. Michael Lauer, who is the Deputy Director of Extramural Research at our National Institutes of Health, and he states, "We know there are companies formed in China for which we funded the research."

So Mr. Chairman, I ask unanimous consent that that——

The CHAIRMAN. Without objection.

[The New York Times article referred to, also entitled "Vast Dragnet Targets Theft of Biomedical Secrets for China" in an online version, follows:]

The New York Times

Vast Dragnet Targets Theft of Biomedical Secrets for China

Nearly 200 investigations are underway at major academic centers. Critics fear that researchers of Chinese descent are being unfairly targeted.

By Gina Kolata

Nov. 4, 2019

The scientist at M.D. Anderson Cancer Center in Houston was hardly discreet. "Here is the bones and meet of what you want," he wrote in a misspelled email to researchers in China.

Attached was a confidential research proposal, according to administrators at the center. The scientist had access to the document only because he had been asked to review it for the National Institutes of Health — and the center had examined his email because federal officials had asked them to investigate him.

The N.I.H. and the F.B.I. have begun a vast effort to root out scientists who they say are stealing biomedical research for other countries from institutions across the United States. Almost all of the incidents they uncovered and that are under investigation involve scientists of Chinese descent, including naturalized American citizens, allegedly stealing for China.

Seventy-one institutions, including many of the most prestigious medical schools in the United States, are now investigating 180 individual cases involving potential theft of intellectual property. The cases began after the N.I.H., prompted by information provided by the F.B.I., sent 18,000 letters last year urging administrators who oversee government grants to be vigilant.

So far, the N.I.H. has referred 24 cases in which there may be evidence of criminal activity to the inspector general's office of the Department of Health and Human Services, which may turn over the cases for criminal prosecution. "It seems to be hitting every discipline in biomedical research," said Dr. Michael Lauer, deputy director for extramural research at the N.I.H.

The investigations have fanned fears that China is exploiting the relative openness of the American scientific system to engage in wholesale economic espionage. At the same time, the scale of the dragnet has sent a tremor through the ranks of biomedical researchers, some of whom say ethnic Chinese scientists are being unfairly targeted for scrutiny as Washington's geopolitical competition with Beijing intensifies.

"You could take a dart board with medical colleges with significant research programs and, as far as I can tell, you'd have a 50-50 chance of hitting a school with an active case," said Dr. Ross McKinney Jr., chief scientific officer of the Association of American Medical Colleges.

The alleged theft involves not military secrets, but scientific ideas, designs, devices, data and methods that may lead to profitable new treatments or diagnostic tools.

Some researchers under investigation have obtained patents in China on work funded by the United States government and owned by American institutions, the N.I.H. said. Others are suspected of setting up labs in China that secretly duplicated American research, according to government officials and university administrators.

The N.I.H. has not named most of the scientists under investigation, citing due process, and neither have most of the institutions involved. "As with any personnel matter, we typically do not share names or details of affected individuals," said Brette Peyton, a spokeswoman at M.D. Anderson.

But roughly a dozen scientists are known to have resigned or been fired from universities and research centers across the United States so far. Some have declined to discuss the allegations against them; others have denied any wrongdoing.

In several cases, scientists supported by the N.I.H. or other federal agencies are accused of accepting funding from the Chinese government in violation of N.I.H. rules. Some have said that they did not know the arrangements had to be disclosed or were forbidden.

In August, Feng Tao, 48, a chemist at the University of Kansas known as Franklin, was indicted on four counts of fraud for allegedly failing to disclose a full-time appointment at a Chinese university while receiving federal funds.

His lawyer, Peter R. Zeidenberg, declined to comment on Dr. Tao's case but suggested that prosecutors were targeting academics nationwide who had made simple mistakes.

"Professors, they get their summers off," he said in an interview. "Oftentimes they will take appointments in China for the summer. They don't believe they have to report that."

"They next thing you know, they are being charged with wire fraud with 20-year penalties," he added. "It's like, are you kidding me?"

The investigations have left Chinese and Chinese-American academics feeling "that they will be targeted and that they are at risk," said Frank Wu, a law professor at the

University of California Hastings School of the Law and former president of the Committee of 100, an organization of prominent Chinese-Americans.

Dr. Wu and other critics said the cases recalled the government's five-year investigation of Wen Ho Lee, a scientist at the Los Alamos National Laboratory who was accused in 1999 of stealing nuclear warhead plans for China and incarcerated for months, only to be freed after the government's case essentially collapsed. He pleaded guilty to a single felony count of mishandling secrets.

More recently, the Justice Department has been forced to drop theft charges against at least four Chinese-American scientists since 2014: two former Eli Lilly scientists in Indiana, a National Weather Service hydrologist in Ohio and a professor at Temple University in Philadelphia. The Justice Department changed its rules in 2016, giving greater oversight over these national security cases to prosecutors in Washington.

But Dr. Lauer and other officials said the investigations into biomedical research have uncovered clear evidence of wrongdoing. In one case at M.D. Anderson, a scientist who had packed a suitcase with computer hard drives containing research data was stopped at the airport on the way to China, Dr. Lauer and officials at the center said.

Overall, they argued, the cases paint a disturbing picture of economic espionage in which the Chinese government has been taking advantage of a biomedical research system in the United States built on trust and the free exchange of ideas.

"How would you feel if you were a U.S. scientist sending your best idea to the government in a grant application, and someone ended up doing your project in China?" Dr. McKinney asked.

'This was something we had never seen.'

Concern at the N.I.H. about the theft of biomedical research stretches back at least to June 2016, when the F.B.I. contacted N.I.H. officials with unusual questions about the American scientific research system.

How did peer review happen? What sort of controls were in place? "They needed to know how our system worked as compared to, say, national defense," Dr. Lauer said.

The F.B.I. declined to discuss ongoing investigations, including why it initiated so many and how targets were selected. But Christopher Wray, director of the F.B.I., told the Senate Judiciary Committee in July that China is using "nontraditional collectors" of intelligence, and is attempting to "steal their way up the economic ladder at our expense."

The F.B.I.'s field office for commercial counterespionage, in Houston, asked administrators from Texas academic and medical centers to attend classified meetings in the summer of 2018 to discuss evidence of intellectual property theft. The administrators were given emergency security clearances and told to sign nondisclosure agreements.

Then, acting on information from the F.B.I. and other sources, the N.I.H. in late August 2018 began sending letters to medical centers nationwide asking administrators to investigate individual scientists.

"This was something we had never seen," Dr. Lauer said. "It took us a while to grasp the seriousness of the problem."

Some of the first inklings of trouble were discovered by administrators at M.D. Anderson, a prominent cancer research and treatment center. Between August 2018 and January 2019, five letters arrived at the center from the N.I.H. asking administrators to investigate the activities of five faculty members.

Dr. Peter Pisters, president of the cancer center, said he and his colleagues reviewed faculty emails, and they turned up disturbing evidence.

Among the redacted emails provided to The New York Times was one by a scientist planning to whisk proprietary test materials to colleagues in China. "I should be able to bring the whole sets of primers to you (if I can figure out how to get a dozen tubes of frozen DNA onto an airplane)," he wrote.

The redacted M.D. Anderson emails also suggest that a scientist at the medical center sent data and research to the Chinese government in exchange for a $75,000 one-year "appointment" under the Thousand Talents Program, which Beijing established a decade ago to recruit scientists to Chinese universities.

Researchers are legally obligated to disclose such payments to the N.I.H. and to their academic institutions, and the scientist had not done so, according to an internal report on the investigation.

Still another scientist at M.D. Anderson had forwarded a confidential research proposal to a contact in China, writing, "Attached please find an application about mitochondrial DNA mutation in tumor development. Please keep it to yourself."

Administrators at M.D. Anderson said three of the scientists had resigned and one had retired. The fifth case involved a scientist whose transgressions may not be serious enough to be fired.

Dr. Xifeng Wu, who left M.D. Anderson and is now dean of the School of Public Health at Zhejiang University in China, declined to comment on the circumstances of her resignation. "I would like to focus on my research," she said.

M.D. Anderson is not the only institution wrestling with possible scientific misconduct.

Last month, two married scientists, Yu Zhou, 49, and Li Chen, 46, who had worked at Nationwide Children's Hospital in Columbus, Ohio, for a decade, were indicted on charges that they stole technology developed at the hospital and used it to apply for Chinese patents and set up biotech companies in China and the United States.

Dr. Zhou's lawyer, Glenn Seiden, said in an email that the couple did not commit any crimes, and that Dr. Zhou is a "trailblazer" in scientific research.

In May, two scientists at Emory University in Atlanta, Dr. Li Xiao-Jiang and Dr. Li Shihua, were fired after administrators discovered that Dr. Li Xiao-Jiang had received funding from China's Thousand Talents Program.

The couple had worked there for more than two decades, researching Huntington's disease. University administrators declined to provide further information.

"They treated us like criminals," Dr. Li Xiao-Jiang said in an interview near Jinan University in southern China, where he and his wife now work. He disputed the suggestion that they had failed to report ties to China.

"Our work is for humanity," Dr. Li Shihua added. "You can't say if I worked in China, I'm not loyal to the U.S."

In July, Dr. Kang Zhang, the former chief of eye genetics at the University of California, San Diego, resigned after local journalists disclosed his involvement with a biotech firm in China that seemed to rely on research he had performed at the university.

Dr. Zhang, also a member of the Thousand Talents Program, did not tell the university about his role. His lawyer, Leo Cunningham, said that Dr. Zhang's suspension was not related to his involvement with the Chinese biotech firm or the program, but instead to his conduct as an investigator in a clinical trial two years earlier.

What is coming to light, Dr. Lauer said, is "a tapestry of incidents."

Start-up companies in China, federal officials say, were founded on scientific and medical technology that the N.I.H. developed with taxpayer money. "We know there are companies formed in China for which we funded the research," Dr. Lauer said.

Some scientists of Chinese descent also secretly received patents in China for research conducted in the United States, according to Dr. Lauer, and some researchers in the Thousand Talents Program signed contracts that require them to provide the Chinese government with confidential results obtained in the United States or other lab discoveries.

"If the N.I.H. funded it, it should be available to U.S. taxpayers," said Dr. McKinney, of the Association of American Medical Colleges. "But if a project is also funded in China, it is moving intellectual property to China."

Espionage or racism?

Federal and academic officials stress that they are not targeting Chinese researchers on the basis of their ethnicity. But the F.B.I.'s silence regarding how so many investigations began has exacerbated concern that the government's efforts to uncover economic espionage may tar all Chinese and Chinese-American scientists — and make it more difficult to recruit Chinese students and scholars.

"We can't tell who is guilty or innocent, but look at the actual effect on people of Chinese descent," said Mr. Wu, the law professor. "People are living in fear. It is a question of impact rather than intent."

With the Trump administration taking a harder line against China, including imposing tariffs intended to punish violations of intellectual property rights, Mr. Wu sees a sharp reversal in attitudes about China and the Chinese.

"I am getting calls and emails constantly now from ethnic Chinese — even those who are U.S. citizens — who feel threatened," he said. But few are willing to step forward with allegations of discrimination, he added.

To Dr. Lauer, the charges of racism are unfounded. "Not all the foreign influence cases involve China," he said. "But the vast majority do."

The real question, he added, is how to preserve the open exchange of scientific ideas in the face of growing security concerns. At M.D. Anderson, administrators are tightening controls to make data less freely available.

People can no longer use personal laptops on the wireless network. The center has barred the use of flash drives and disabled USB ports. And all of its employees' computers can now be monitored remotely.

The N.I.H. is clamping down, too. It recommends that reviewers of grant applications have limited ability to download or print them. Those traveling to certain regions should use loaner computers, it says, and academic institutions should be alert to frequent foreign travel by scientists, or frequent publishing with colleagues outside the United States.

The National Science Foundation has commissioned an independent scientific advisory group to recommend ways of balancing openness and security, and warned employees that they are prohibited from participating in programs like China's Thousand Talents Program.

The F.B.I. has given research institutions tools to scan emails for keywords in Mandarin that might tip off administrators to breaches, according to Dr. McKinney.

"The effects this will have on long-term, trusting relationships are hard for us to face," he said. "We just are not used to systematic cheating."

Gina Kolata writes about science and medicine. She has twice been a Pulitzer Prize finalist and is the author of six books, including “Mercies in Disguise: A Story of Hope, a Family's Genetic Destiny, and The Science That Saved Them.” @ginakolata Facebook

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Senator BARRASSO. Then my final question. Universities pride themselves on conducting open science. It includes collaboration with foreign nations. Understandable. The international collaboration really may help advance science, but as a 2019 FBI report states—and here is the FBI report. It states, "This open environment also puts academia at risk for exploitation by foreign actors."

So before Congress radically increases funding to boost our competitiveness with China, shouldn't we ensure that universities have safeguards in place to prevent China from benefiting from this funding?

Mr. Chairman, I ask unanimous consent to be able to put that in the record as well.

The CHAIRMAN. Without objection.

[The 2019 FBI report referred to follows:]

As of March 2018, more than 1.4 million international students and professors were participating in America's open and collaborative academic environment. The inclusion of these international scholars at U.S. colleges and universities entails both substantial benefit—and notable risk. Many of these visitors contribute to the impressive successes and achievements enjoyed by these institutions, which produce advanced research, cutting-edge technology, and insightful scholarship. However, this open environment also puts academia at risk for exploitation by foreign actors who do not follow our rules or share our values.

The annual cost to the U.S. economy of counterfeit goods, pirated software, and theft of trade secrets is
$225–$600 BILLION

The vast majority of the 1.4 million international scholars on U.S. campuses pose no threat to their host institutions, fellow classmates, or research fields. On the contrary, these international visitors represent valuable contributors to their campuses' achievements, providing financial benefits, diversity of ideas, sought expertise, and opportunities for cross-cultural exchange. Any research institution hoping to be—and to remain—among the best in the world must attract and retain the best people in the world, wherever they are from. The FBI recognizes, and values, this unique package of benefits these international students and professors provide.

However, some foreign actors, particularly foreign state adversaries, seek to illicitly or illegitimately acquire U.S. academic research and information to advance their scientific, economic, and military development goals. By doing so, they can save their countries significant time, money, and resources while achieving generational advances in technology. Through their exploitative efforts, they reduce U.S. competitiveness and deprive victimized parties of revenue and credit for their work. Foreign adversaries' acquisition efforts can come in many forms, including overt theft, plagiarism, elicitation, and the commercialization of early-stage collaborative research.

As foreign adversaries use increasingly sophisticated and creative methodologies to exploit America's free and open education environment, the United States faces an ever-greater challenge to strike a sustainable balance between unrestricted sharing and sufficient security within this education ecosystem. Through a whole-of-society approach that includes increased public awareness, academic vigilance, industry self-protection, government and law enforcement collaboration, and legislative support, the U.S. higher education system can continue to enjoy the manifold contributions that international academics provide, while minimizing the risk they (and their affiliated home governments) pose to U.S. security priorities. The FBI maintains that striking this balance is possible and necessary.

Foreign adversaries exploit America's deeply held and vital culture of collaboration and openness on university campuses, with the Chinese government posing a particular threat to U.S. academia for a variety of reasons. First, it does not play by the same rules of academic integrity that U.S. educational institutions observe. Many recent high-profile examples show plagiarism is commonplace throughout Chinese academic and research institutions. Illustrative of this endemic plagiarism, when the *Journal of Zhejiang University–Science* became the first in China to employ text analysis software to identify plagiarism in 2008, its analysis of articles published over a two-year period found approximately 31% of papers exhibited "unreasonable" copying and plagiarism, according to the journal director.

Second, the Chinese government has historically sponsored economic espionage, and China is the world's principal infringer of intellectual property. The annual cost to the U.S. economy of counterfeit goods, pirated software, and theft of trade secrets is between $225 billion and $600 billion.

Lastly, while the vast majority of students and researchers from China are in the United States for legitimate academic reasons and contribute to the diversity of backgrounds and ideas important in our society, the Chinese government uses some Chinese students—mostly post-graduate students and post-doctorate researchers studying science, technology, engineering, and mathematics (STEM)—and professors to operate as non-traditional collectors of intellectual property. These Chinese scholars may serve as collectors—wittingly or unwittingly—of economic, scientific, and technological intelligence from U.S. institutions to ultimately benefit Chinese academic institutions and businesses.

Regardless of motive, this exploitation comes at great cost to U.S. interests. When these foreign academics unfairly take advantage of the U.S. academic environment, they do so at a cost to the institutions that host them, as well as to the greater U.S. innovation ecosystem in which they play a role. Directly or indirectly, their actions cost money, jobs, expertise, sensitive information, advanced technology, first-mover advantage, and domestic incentive to innovate.

The FBI values academic integrity and rules-based scholarship, and we recognize international academics infuse campuses—and greater U.S. society—with a diversity of ideas that helps fuel the continued growth of the U.S. economy. According to the current numbers, immigrants—including many who first came to America as international students—founded almost a quarter of all new U.S. businesses, nearly one-third of our venture-backed companies, and half of Silicon Valley's high-tech startups. More than 18% of Fortune 500 companies were founded by immigrants.

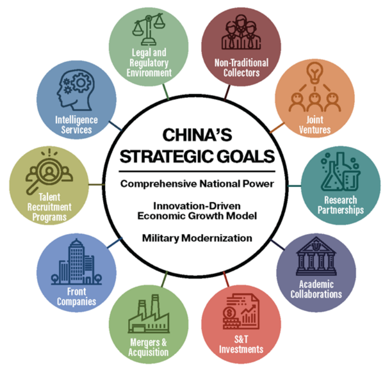
Academic environments represent the very bedrock on which this country is built and upon which its future depends. These campuses are where young minds from diverse background and countries discover new technologies, learn novel concepts, establish crucial connections, pursue innovation, and lay the groundwork for America's continued leadership in scholarship and technology advancement for decades to come. If these open, free, and collaborative environments are compromised, limited, or obstructed, all of us here today—and the country's future generations—lose. We want to work with you to address these challenges.

DIFFERENCES IN BUSINESS PRACTICES

UNITED STATES	CHINA
Generally accessible market	Highly restrictive market
Market economy	State-run economy
Development by innovation	Development by theft, replication, and commercialization
Independent judiciary and separation of powers	Judiciary subordinate to the government
Laws protecting intellectual property	Unequal protection of intellectual property
No government-sponsored economic espionage	Government-sponsored economic espionage

CHINA'S DEVELOPMENT STRATEGY

The Chinese government's strategic goals include becoming a comprehensive national power, creating innovation-driven economic growth, and modernizing its military. It aspires to equal or surpass the United States as a global superpower and influence the world with a value system shaped by undemocratic, totalitarian ideals. Using a whole-of-society approach to achieve these goals, the Chinese government takes advantage of every opportunity—from academic collaboration to economic espionage—to develop and maintain a strategic economic edge.



To achieve its economic, technological, and military goals, the Chinese government relies on various state-directed plans. These plans provide insight into the kinds of knowledge, research, intellectual property, and trade secrets the country targets and seeks to acquire from foreign sources. At present, China's government has as many as 100 plans guiding China's foreign acquisition, and their scale and influence are impressive. Two of the most important among these plans include the 13th Five-Year Plan and the Made in China 2025 Plan, both of which help to guide the country's overall strategic direction.

The Made in China 2025 Plan lists 10 domestic Chinese industries from which the government of China seeks to eliminate any foreign-produced technology:

- Information technology
- Computer numerical control machine tools and robotics
- Aerospace equipment
- Marine engineering equipment and high-tech ships
- Advanced rail transportation equipment
- Energy-efficient and new-energy automobiles
- Electric power equipment
- Agricultural equipment
- New materials
- Biomedicine and high-performance medical instruments

ACCORDING TO THE CHINESE GOVERNMENT'S STATE COUNCIL, CHINA USES THE FOLLOWING FOUR-STEP DEVELOPMENT PROCESS TO GAIN A TECHNOLOGICAL EDGE:

1 INTRODUCE	The Chinese government uses numerous methods—some legitimate but others, such as stealing technology from foreign competitors, meant to illicitly **introduce** foreign technology and knowledge to China.
2 UNDERSTAND	The Chinese government uses its numerous civilian and military institutions and resources to **understand** the materials acquired from foreign sources.
3 ASSIMILATE	Those same institutions **assimilate** foreign technology and knowledge into Chinese infrastructure—frequently by reverse-engineering it.
4 RE-INNOVATE	Chinese institutions **re-innovate** foreign technologies, such as military aircraft, high-speed trains, and nuclear reactors, to develop new and state-of-the-art technology. Such advances allow China to achieve generational advances and save time and money on research and development.

FOREIGN TRADECRAFT USED AGAINST ACADEMIA

Academic Targets of Foreign Adversaries

If your university or institution's research has technical applications, expect foreign adversaries to target it. If your university or institution invests significantly in expensive research and development, anticipate foreign adversaries will target it—including those conducting the research and the development processes you use to produce your end products. Some of the information these adversaries target might seem insignificant, but by bypassing the research and development phase and stealing your technical information or products, foreign adversaries can gain a competitive economic and military advantage.

Research can lead to the development of products with national security applications. Even if the technologies and their applications are not currently classified, they could be in the future. Foreign adversaries know this and seek to obtain this technology when it is least restricted and easiest to obtain: before it is classified.

Foreign adversaries might target your:

- Students, professors, and researchers with access to research and technical information (particularly graduate and post-doctorate students)
- Pre-publication research results
- Research data
- Techniques and processes
- Laboratory equipment and software
- Pre-classification research
- Access protocols
- Budget estimates and expenditures
- Computer access protocols
- Computer network design
- Customer and employee data
- Equipment specifications
- Passwords for your computer, phone, or accounts
- Phone and property data
- Proprietary research, formulas, and processes
- Prototypes or blueprints
- Software, including source codes
- Technical components and plans
- Vendor information and supply chain
- Confidential documents
- Grant data

CASE EXAMPLE

A Chinese researcher at a Midwestern medical school was charged with economic espionage for illegally acquiring an American researcher's patented cancer research and transferring it to a university in China. The American researcher placed several containers of a patented cancer research compound on his desk, stepped away, and found them gone when he returned. The university's review of security surveillance footage showed the Chinese researcher was the only other individual who had entered the American researcher's office that day. The Chinese researcher had also accessed the university's computer server and attempted to delete proprietary information related to the research and compound. When questioned by law enforcement, the Chinese researcher indicated he could not understand English, despite his coworkers' assurances he spoke the language well and had lived in the United States for several years. He was arrested only days before he was scheduled to fly to China and ultimately pleaded guilty to intentionally accessing a computer without authorization and obtaining information worth more than $5,000.

This case highlights the vulnerability even protected, patented materials and information face due to the open, collaborative environment of U.S. academic institutions, further emphasizing the need for constant vigilance and proactive protection. This case also highlights the tremendous incentives foreign governments such as China are offering to their citizens to produce or procure (by whatever means necessary) cutting-edge research and technology through research funding and talent recruitment efforts.

THE CHINESE GOVERNMENT USES A WHOLE-OF-SOCIETY APPROACH TO ADVANCE ITS ECONOMIC DEVELOPMENT, ACHIEVE GENERATIONAL ADVANCES IN RESEARCH AND DEVELOPMENT, AND SAVE MONEY. YOUR UNIVERSITY OR INSTITUTION'S PROFESSORS, STUDENTS, OR RESEARCH MIGHT BE TARGETED.

CASE EXAMPLE

An American aerospace engineering professor at a Michigan university accepted a Chinese student's request to study with him. The student indicated she was affiliated with a Chinese civilian institution and expressed an interest in the professor's work. However, her China-based address in the university directory corresponded to a college for Chinese military officers, and she had previously published an article about improving China's anti-satellite technology. According to the professor, the Chinese student pressured him to reveal secrets about his work and was likely interested in research with military satellite applications.

This case describes how foreign adversaries like China sometimes task students to hide connections to a foreign government—in this case, a foreign military. To combat theft of technology and research, colleges and universities should consider proactive steps to ensure students and faculty understand how to protect intellectual property effectively, how to share and protect information responsibly, and how to avoid potential threats or compromises before they arise. Universities, as stewards of taxpayer research dollars, should consider implementing and enforcing clearer—and, in some cases, more restrictive—guidelines regarding funding use, lab access, collaboration policy, foreign government partnership, nondisclosure agreements, and patent applications. Additionally, the more willing colleges and universities are to engage with U.S. law enforcement as issues arise and suspicious circumstances become noticed, the more likely it is that the FBI and its partners can help to mitigate risk or minimize damage to these colleges and universities.

Tactics Foreign Adversaries Use to Target U.S. Academia

Foreign adversaries leverage joint research opportunities, language and cultural training, unsolicited invitations, visiting students and professors, and state-sponsored industrial and technical espionage to support their military and commercial research, development, and acquisition.

The tactics below all represent legitimate opportunities for your university or institution. However, foreign adversaries might use any combination of them to strategically target you and your work.

TALENT RECRUITMENT OR "BRAIN GAIN" PROGRAMS encourage the transfer of original ideas and intellectual property from U.S. universities. For example, China's talent recruitment plans, such as the Thousand Talents Program, offer competitive salaries, state-of-the-art research facilities, and honorific titles, luring both Chinese overseas talent and foreign experts alike to bring their knowledge and experience (or that of advisors and colleagues) to China.

Association with talent recruitment plans by itself is not illegal; however, potential participants and their employers should be aware of legal issues that may arise as a result of participation, including violation of export-control laws, economic espionage, or violation of employer conflict-of-interest policies. A simple download of intellectual property or proprietary information has the potential to become criminal activity.

FOREIGN STUDENTS OR VISITING PROFESSORS are usually studying or working at U.S. universities for legitimate reasons. However, some foreign governments coerce legitimate students into reporting on the research they are doing in the Unites States—or even offer scholarships or funding in exchange for the information.

LANGUAGE AND CULTURAL TRAINING opportunities can enable foreign adversaries to use universities not only to increase their understanding of the local language and culture, but also to make contacts.

FUNDING AND DONATIONS provided by foreign adversaries can enable universities to establish cultural centers, support academic programs, or facilitate joint research while also fostering goodwill and trust between the donor organization and university. However, a foreign adversarial funding organization could place stipulations on how the programs or centers function or install its own recruits in positions with little or no university oversight.

ELICITATION of information about your research or work can come in many forms. A foreign adversary might try to elicit information by using flattery, assuming knowledge, asking leading questions, claiming a mutual interest, or feigning ignorance.

JOINT RESEARCH OPPORTUNITIES and collaborative environments, such as incubators or joint research centers, can enable a foreign adversary to obtain your research. They can also provide an opportunity to spot, assess, and befriend fellow STEM students or researchers who might assist—either wittingly or unwittingly—in passing your research and development to a foreign adversary.

FOREIGN TRAVEL can leave American students, professors, and researchers vulnerable to targeting through searches of luggage and hotel rooms, extensive questioning, manufacture of compromising situations, and confiscation of electronics. Foreign governments do not operate under the same laws or observe the same privacy rights that the U.S. government observes.

FOREIGN VISITORS entering sensitive research areas can pose a security risk to your intellectual property or competitive edge. Some visitors might verbally elicit information, some might brazenly ignore the security parameters of a tour, and others might use concealed electronic devices to obtain restricted information or access.

CASE EXAMPLE

A well-known U.S. professor obtained a U.S. Air Force–funded contract to develop specialized plasma technology to control the flight of military drone aircraft. The professor inappropriately allowed two international students to work with him on the government-backed research and permitted the foreign nationals to access restricted, export-controlled data and equipment. The professor also illegally traveled to China with a laptop containing export-controlled research data—even though his university had counseled that the data must remain in the United States. The U.S. professor was convicted of conspiracy, wire fraud, and 15 counts of exporting defense articles and services without a license.

This example illustrates how universities can protect theft of technology from foreign adversaries by implementing and enforcing clear—and in some cases more restrictive—guidelines regarding funding use, lab access, collaboration policy, foreign government partnership, and nondisclosure agreements.

CASE EXAMPLE

A Chinese professor at a U.S. university contributed to a classified U.S. Department of Defense project. He was also a member of the Thousand Talents Program and an advisor for the Chinese government's Institute of Electronics and Automation Engineering at a Chinese university—as well as the lead scientist for an advanced technology project at a major Chinese research institute. The Chinese professor provided the Chinese institute with research that closely resembled the classified work he had performed for the U.S. Department of Defense.

This example shows the threat posed by programs like the Thousand Talents Program. Intentional or not, foreign governments' talent recruitment and "brain gain" programs encourage theft of intellectual property from U.S. universities. China's talent recruitment plans, such as the Thousand Talents Program, offer competitive salaries, state-of-the-art research facilities, and honorific titles, luring both Chinese overseas talent and foreign experts alike to bring their knowledge and experience (or that of advisors and colleagues) to China at the expense of the United States.

Spotting Students or Professors

Foreign intelligence services routinely collect information about U.S. universities' programs, administrators, professors, and demographics. Foreign adversaries might target students and researchers with current or future access to sensitive information, including studying their motivations, weaknesses, politics, ambitions, and previous work. They can spend years targeting an individual and developing a relationship that leads the student, professor, or researcher—either wittingly or unwittingly—to provide information to the foreign adversary.

Foreign adversaries are particularly interested in American students or researchers traveling overseas who are sponsored by the U.S. government; conducting research with future, potentially classified applications; or seeking future U.S. government employment.

Foreign adversaries might use any of these techniques to access information or research via students, professors, or researchers:

- Appeals to ethnicity or nationality (for example, common ethnic heritage or dual-citizenship)
- Sponsorship of foreign travel
- Coercion
- Study abroad opportunities
- Overseas professional opportunities
- Talent recruitment programs
- Social engineering
- Scholarships or research funding
- Publishing opportunities
- Joint research opportunities

CASE EXAMPLE

American citizen Glenn Duffie Shriver was an undergraduate studying in Shanghai when he responded to an ad in a Chinese newspaper soliciting essays on U.S.-China relations. Shriver's essay submission led to interactions with three Chinese intelligence officers who represented themselves as municipal government officials. They developed a relationship with Shriver over time and eventually asked him to return to the United States and obtain employment with the U.S. government. After graduating, Shriver spent the next five years attempting to gain employment with the U.S. Department of State and the Central Intelligence Agency (CIA), all the while maintaining contact with the intelligence officers and accepting $70,000 from them. Shriver knew the purpose of his intended U.S. government employment was to gain access to national defense information and provide it to the Chinese government. While he was being processed for employment with the CIA, Shriver made false statements to conceal his relationship with the Chinese intelligence officers. He was arrested in 2010 and subsequently pleaded guilty to conspiracy to provide national defense information to a person not entitled to receive it. The following year, he was sentenced to four years in prison. The FBI's short film *Game of Pawns: The Glenn Duffie Shriver Story* is based on these events. Accessible at www.fbi.gov, the film educates viewers about the foreign intelligence threat Americans face abroad.

This example shows that foreign intelligence services seek to identify U.S. students who can help them gain access to information or persons of interest—either immediately or in the future. Foreign intelligence services develop initial relationships with U.S. students overseas under seemingly innocuous pretexts, such as job or internship opportunities, paid paper writing engagements, language exchanges, and cultural immersion programs. As these relationships develop, foreign intelligence services ask the U.S. students to perform tasks and provide information (which is not necessarily sensitive or classified) in exchange for payment or other rewards, slowly increasing their demands over time. Without proper awareness about this threat, U.S. students overseas have inadvertently become involved in espionage activities and have been prosecuted for these activities.

Insider Threats

Your university or institution may be vulnerable to damage from an insider—someone who has legitimate or illegitimate access to your information or research and provides that information to a foreign adversary. Insider threats could begin as early as the application phase, when applicants might be directed by foreign governments to seek enrollment in, or employment with, universities or research institutions with access to desired programs and persons.

Some of these behaviors might indicate an individual potentially poses an insider threat to your university or institution:

- Displays suitability issues, such as alcohol or drug abuse
- Insists on working in private
- Volunteers to help on classified or sensitive work
- Expresses an interest in covert activity
- Has unexplained or prolonged absences
- Rummages through offices or desks of others
- Misuses computer or information systems
- Attempts a computer network intrusion
- Has criminal contacts or associates
- Employs elicitation techniques
- Displays unexplained affluence
- Fails to report overseas travel, if required
- Takes classified or sensitive material home without authorization
- Conceals foreign contacts
- Lacks concern for or violates security protocols
- Brings audio or visual recording devices into work areas without authorization
- Unnecessarily photocopies or downloads sensitive material
- Attempts to gain access without a need to know
- Shows unusual interest in information outside the scope of his or her role
- Takes short trips to foreign countries for unexplained reasons

CASE EXAMPLE

A Chinese-American employee at a U.S. university established an internship placement service for American students interested in traveling to China for student exchanges. However, the employee was also knowingly in contact with a Chinese intelligence officer who targeted American students for intelligence exploitation. The employee provided the intelligence officer with personal and identifying information about American graduate students in China, including their travel logistics, contacts, and studies. The following year, the employee provided the Chinese intelligence officer with email communications between the U.S. university and a U.S. company that managed international education programs in China. The employee then provided the Chinese intelligence officer with résumés, interview information, and personal data to facilitate the targeting of students at several U.S. universities.

This example shows that foreign intelligence services seek to identify U.S. students who can help them gain access to information or persons of interest—either immediately or in the future. Foreign intelligence services develop initial relationships with U.S. students overseas under seemingly innocuous pretexts, such as job or internship opportunities, paid paper writing engagements, language exchanges, and cultural immersion programs. As these relationships develop, foreign intelligence services ask the U.S. students to perform tasks and provide information (which is not necessarily sensitive or classified) in exchange for payment or other rewards, slowly increasing their demands over time. Without proper awareness about this threat, U.S. students overseas have inadvertently become involved in espionage activities and have been prosecuted for these activities.

Foreign adversaries look for opportunities to exploit individuals' vulnerabilities and motivations to gain access to your research and development. In the past, foreign adversaries have targeted the following vulnerabilities and situations when exploiting insiders:

- Ideology (such as divided loyalty to a country other than the United States)
- Professional or academic opportunities, such as conferences
- Greed or financial stress
- Ego or self-image
- Coercion or compromise
- Anger, revenge, or disaffection
- The need for adventure or thrills

Cyber Techniques

Foreign adversaries might conduct computer intrusions by writing or manipulating computer code to gain access to, or install unwanted software on, your network. To do so, they could employ a variety of techniques.

CLICK-BAITING is when an adversary conceals hyperlinks beneath legitimate clickable content (such as "Like" and "Share" buttons on social networking sites). Once clicked, the links cause a user to unknowingly perform unwanted actions, such as downloading malware or sending the user's ID to a third party.

PHISHING is when an adversary conceals a link or file containing malware in something like an email, text message, or social media message that looks like it is from a legitimate organization or person. If clicked, the link or file compromises the recipient's electronic device and/or associated account.

SOCIAL ENGINEERING is when an adversary tricks a user into divulging confidential or personal information that may be used for fraudulent purposes.

UNPATCHED SOFTWARE EXPLOITATION is when an adversary takes advantage of people or companies that do not update their software regularly to conduct malicious activity, such as computer exploitation or malware installation.

SOCIAL MEDIA EXPLOITATION is when an adversary uses social media networks to exploit a user's personal connections—including his or her profile, content, and interactions on social media websites—to spot and assess employees for potential recruitment.

CASE EXAMPLE

After the FBI alerted it to a cyberattack on its College of Engineering's network, a large northeastern state university enlisted a third-party expert to identify the nature of the attack and take appropriate action. The third-party investigation revealed the presence of two sophisticated, previously undetected threat actors and confirmed at least one of the two attacks emanated from a threat actor based in China with a history of targeting victims in aerospace, defense, and academia. Evidence linked the China-based actor directly to the compromise of usernames and passwords issued by the College of Engineering and accessed via its network. The third-party investigation also revealed the university's network had been compromised for at least two years.

The university president said in a letter to the university community, "As we have seen in the news over the past two years, well-funded and highly skilled cybercriminals have become brazen in their attacks on a wide range of businesses and government agencies, likely in search of sensitive information and intellectual property." On an average day, the university blocks more than 20 million cyberattacks from around the world.

HOW TO PROTECT YOUR UNIVERSITY OR INSTITUTION

Your organization could consider adopting some of these suggested measures to identify and combat potential insider threats. Depending on your company's specific needs, policies, processes, and legal guidelines, you should determine what security measures are necessary to sufficiently protect your company's most important assets.

- Educate and regularly train employees on security policies and protocols.
- Ensure proprietary information is carefully protected.
- Employ appropriate screening processes to hire new employees.
- Develop strong risk management and compliance programs.
- Provide convenient ways for employees to report suspicious behavior, and encourage such reporting.
- Monitor computer networks routinely for suspicious activities.
- Provide security personnel with full access to relevant human resources data.
- Ensure physical security personnel and information technology security personnel have sufficient threat detection software, countermeasure tools, and protective processes in place.
- Implement a continuous evaluation program to persistently screen onboard employees.
- Conduct in-depth background checks on potential partners for associations with state-sponsored entities.
- Ensure retired, separated, or dismissed employees turn in all company-issued property.
- Ensure sufficiency of existing nondisclosure agreement requirements and policies restricting the removal of company property.

It is every university and institution's responsibility to safeguard its information. The FBI actively partners with universities and institutions to support this effort, providing counterintelligence tools and awareness training to help your schools and scholars recognize suspicious behavior and better protect your facilities and information. The FBI can collaborate with U.S. universities or institutions on a wide variety of topics, including:

- Responsibly performing U.S. government-funded research
- Countering foreign intelligence services' attempts to recruit U.S. students and professors
- Safeguarding personal and sensitive information
- Employing best practices for domestic and overseas campus safety
- Employing effective cybersecurity measures

Develop a Security Strategy

Ensure you have a security strategy to protect your institution's information and employees from potential physical and cyber threats. To develop this strategy, identify your most important research and assets and ensure you devote appropriate resources to their protection. Establish formal agreements and procedures to determine ownership of intellectual property.

Develop a prevention, recognition, and response plan tailored to addressing insider, foreign adversary, and cyber threats. Form teams made up of legal counsel, cyber experts, physical security specialists, and academic supervisors to specifically combat insider threats. Ensure your university or institution's response policies can be easily accessed by employees and that they adequately account for privacy and confidentiality.

Talk to your local FBI field office to report any suspicious activities, request training, or ask for threat and awareness materials to ensure you remain up to date on evolving threats.

Combating Foreign Adversaries' Tactics to Target Your University or Institution

ACADEMIC COLLABORATION is necessary to advance knowledge. Simple security measures, however, can go a long way in preventing the loss of current research and future opportunities. Consider the hidden risk of unsolicited offers for employment, research collaboration, or conference attendance.

FOREIGNER VISITS can present potential vulnerabilities to sensitive university facilities. Keep visitor groups together and monitor them at all times during the duration of their visit to areas containing sensitive technology, products, or personal information. When possible, ensure all visitors have proper clearance and background checks before they enter your facilities. Be aware of last-minute additions to visitor lists, as foreign adversaries sometimes add individuals at the last minute in an attempt to steal your information. Prevent unauthorized access to computer systems and ensure visitors do not record building security access procedures by ensuring visitors do not take videos or photographs or plug portable media devices into university computers.

MALICIOUS CYBER ACTIVITY can also present potential vulnerabilities. Monitor logs on these systems to better identify this activity:

- Firewalls
- Proxy
- Web Server
- Anti-virus
- Active directory
- Network Address Translation (NAT)
- Windows event
- Intrusion Detection System (IDS)
- Domain Name Server (DNS)

If you suspect a cyber intrusion, assess the nature and scope of the incident by isolating the affected systems, target, and origin of the activity. Collect the network logs and records. Implement your company's cyber response plan and report the incident to law enforcement.

When in Doubt, Report the Incident

When in doubt, report a security violation or cyber intrusion to your institution's security officer or your local FBI office. *Do not* alert the person under suspicion. Your security officers or law enforcement partners will handle the interaction according to their response policies.

Although your first inclination might be to distance your university or institution from a harmful threat, terminate an employee, or expel a student, there is significant value in reporting a security violation or cyber intrusion to law enforcement. Monitoring and investigating the threat could uncover third party actors and reveal previously unknown vulnerabilities of your university or institution.

WAYS YOU CAN PROTECT YOUR ORGANIZATION There are steps organizations may take to identify and deter potential threats. The FBI offers these for information, but each organization must assess applicability in terms of its own policies, processes, and legal guidelines.	NON-TRADITIONAL COLLECTORS*	INSIDER THREATS	JOINT VENTURES	FRONT COMPANIES	CYBER
Conduct exit interviews to identify potential high-risk employees (such as terminated employees and retired employees with insider threat indicators)	●	●		●	
Create a program that regularly screens employees for insider threats	●	●	●	●	
Develop strong risk management and compliance programs			●	●	
Educate and regularly train employees on security policies and protocols	●	●	●	●	●
Employ appropriate screening processes to hire new employees	●	●	●	●	●
Encourage responsible use of social media sites and ensure online profiles have proper security protections in place					●
Ensure the company in question has been vetted through diligent research			●	●	
Ensure physical security personnel and information technology security personnel have the tools they need to share information	●	●	●	●	●
Ensure proprietary information is carefully protected	●	●	●	●	●
Ensure retired, separated, or dismissed employees turn in all company-issued property	●	●			●
Establish Virtual Private Networks (VPNs) for added protection					●
Evaluate the use of nondisclosure agreements and policies restricting the removal of company property	●	●		●	
Install Intrusion Detection Systems (IDSs)					●
Monitor computer networks routinely for suspicious activities	●	●	●		
Negotiate joint venture terms and penalize actions that contradict the agreement			●		
Provide nonthreatening, convenient methods for employees to report suspicious behavior, and encourage such reporting	●	●	●	●	●
Provide security personnel with full access to human resources data	●	●	●	●	
Routinely monitor computer networks for suspicious activities	●	●		●	●
Update software, firewalls, and anti-virus programs					●

**A non-traditional collector is an individual who is not operating on behalf of an intelligence service but who collects information from the United States and other foreign entities to support foreign government–directed objectives.*

For More Information

Training Materials		
ORGANIZATION	**CONTACT**	**DETAILS**
Center for Development of Security Excellence	http://cdse.edu/catalog/elearning/INT101.html	*Insider Threat Awareness Course (INT101. 16)*
Center for Development of Security Excellence	http://www.cdse.edu/toolkits/insider/index.php	*Insider Threat Toolkit*
Software Engineering Institute, Carnegie Mellon University	https://resources.sei.cmu.edu/library/asset-view.cfm?assetID=484738	*Common Sense Guide to Mitigating Insider Threats, Fifth Edition*
Federal Bureau of Investigation	http://www.fbi.gov	Numerous publications and videos on the threat from foreign adversaries targeting U.S. businesses.

Additional Contacts	
ORGANIZATION	**CONTACT INFORMATION**
FBI Field Offices	https://www.fbi.gov/contact-us/field-offices
FBI Internet Crime Complaint Center	http://www.ic3.gov
National Cyber Investigative Joint Task Force	855.292.3937 | cywatch@fbi.gov
National Cybersecurity and Communications Integration Center, U.S. Department of Homeland Security	888.282.0870 | NCCIC@hq.dhs.gov

CONTACT US:

For more information, contact your local field office at *https://www.fbi.gov/contact-us/field-offices*

Mr. DABBAR. Senator, yes, I would agree with you. OSTP has recommended certain policies to universities to try to identify conflict of interest and disclosure which are the first steps to identifying the problem and to set up solutions. There's some universities that are much farther along on this, on the China acquisition of technology and there are some that are less. And I think that process should continue forward and would certainly recommend that you include certain provisions in anything to enhance that.

Senator BARRASSO. Okay.

Dr. MASON. And if I could just add to that?

I'm actually serving on something called the Round Table for Science and Security that was set up by the National Academies of Sciences, actually under the auspices of this interagency process that Paul was talking about and that's bringing together academic institutions, national labs, that's my role there, government agencies who are funding research and people with experience in the intelligence community. And one of the things that we're grappling with is this challenge of, you know, equipping the universities to respond to this without actually, you know, killing the goose that laid the golden egg. We want to retain that ability for free and open and innovative research, but we need to be smarter about how we go about doing it in some of these areas that cut a little bit closer to the edge in terms of our national and economic security. And as Mr. Dabbar has stated, I think there are many universities that have a deep appreciation of this because of the challenges they faced and the experiences they've had. There are others where it's still a bit of an alien concept and we have some work to do to educate.

Senator BARRASSO. Thank you for your answer.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Let me again reiterate our appreciation—what you have brought to the Committee today and been able to share with us, your knowledge and your professionalism and also the experiences you have had, has been tremendous. I know that Dr. Pierpoint could not be here, but we are so happy that she was able to join us by WebEx, and we thank her. Ms. Ladislaw, we thank you, Mr. Dabbar, Dr. Mason.

We are in a situation right now where there are an awful lot of things coming and we are trying to decide how we best go forward to get the biggest bang for our buck but make sure we are not reinventing the wheel or spending doubly for something we already have. So we are going to be probably calling on you more in the near future and we would like to have your input and we appreciate, again, very much for making an effort to be here.

This meeting is adjourned.

Oh, I'm sorry, I'm sorry. I have to make one more statement here.

Members will have until close of business tomorrow to submit additional questions for the record.

Now the meeting is adjourned.

[Whereupon, at 12:07 p.m. the Committee adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
April 15, 2021 Hearing: *The Leading Role of the Department of Energy in American Energy Innovation and How Its Research, Development, Demonstration, and Deployment Programs may be Enhanced to Further Boost the Economic Competitiveness of the United States*
Questions for the Record Submitted to Dr. Thomas Mason

Questions from Chairman Joe Manchin III

Question 1: We often describe our national labs as the "crown jewels" of research and development.

a. Could you describe in detail – based on your experience leading Oak Ridge National Lab and now Los Alamos National Lab – what the non-energy R&D talents of the labs include?

DOE's overarching mission, and thus that of the National Laboratories, is to advance the national, energy, and economic security of the United States. The R&D talents of the national labs are all tied to some aspect of this mission, including a direct or indirect connection to energy R&D. The Labs provide world leading expertise in many areas that may not have an obvious or direct connection to energy R&D but contribute to that and other DOE missions, including areas such as deterrence, high performance computing, quantum science, artificial intelligence/machine learning, biology, chemistry, geology, and materials science to just mention a few. DOE is the largest funder of research in the physical sciences in the U.S. and many of the underlying scientific bases for the energy and national security missions have broader potential impacts. In addition, the experimental (light sources, neutron sources, electron microscopes, nano science centers) and computational facilities are used by researchers funded by industry and other government agencies including NSF and NIH.

b. How do non-lab researchers partner with or otherwise use the lab resources and expertise?

The National Laboratories occupy a unique niche in our country's R&D ecosystem. They complement the roles and capabilities of academic and industrial research efforts, and are also important collaborators with both on fundamental and applied research. They also support the training of thousands of future scientists and engineers educated at America's colleges and universities. There are several different ways in which this collaboration takes place, through national user facilities, institutes and consortia, student programs, and research agreements.

DOE user facilities are often larger, world-class facilities with unique instrumentation that are open and accessible to university, industry, and government scientists based on the merit of their research proposals. Those scientists, or "users" as they are often called, are aided by thousands of national lab scientists and technicians who understand and help users fully leverage the technical capabilities of the facility to produce the best science. These user facilities are generally of a size, scale, and complexity beyond the management expertise of most universities and beyond the risk tolerance of corporations, and include particle accelerators, experimental reactors, x-ray synchrotron and free-electron laser light sources, leadership-class supercomputers and other high-precision instruments. In 2019, more than 36,000 researchers from universities, industry, and government conducted experiments at user facilities funded and operated by DOE. These experiments range from isotope research for medical purposes, advanced computing, fusion, biological and environmental research, quantum materials and information sciences, and many others.
DOE not only sponsors individual researchers through various program offices, including ARPA-E and the Office of Science, but also numerous consortia at various scales and on a variety of topics. At the smaller end of the scale, DOE sponsors Energy Frontier Research Centers (EFRCs) that bring together small multidisciplinary teams of lab and non-lab scientists to address the toughest scientific challenges to advancing energy technologies, including materials and chemistry for microelectronics and QIS, chemical upcycling, batteries, environmental cleanup, and more. Receiving $2 million to $4 million per center per year, there are currently 41 EFRCs in 34 states engaging approximately 650 senior researchers and over 1,600 students, postdoctoral fellows, and technical staff at 105 universities and other institutions. Bioenergy Research Centers (BRCs), Energy Innovation Hubs, and National QIS Research Centers bring together larger multidisciplinary teams of national lab, university, and industry scientists for purpose-driven research spanning from fundamental science to technology development and commercialization with funding of approximately $25 million per center per year. For instance, there are four BRCs – two led by universities and two led by national laboratories – whose mission is to break down barriers to realizing a strong, domestic bioenergy and bioproducts industry. The effort involves over 35 university and industry partners and at least eight national laboratories. The Energy Innovation Hubs and National QIS Research Centers follow a similar model sponsoring collaborative research that leverages the contributions of national lab, university, and industry to achieve specific goals.

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Our laboratories rely upon recruiting the best and the brightest that our universities have to offer. Often times this starts through internship, graduate, and post-graduate programs. These programs allow students access to the many unique tools that the National Labs offer. They also allow the laboratories to help identify students that fit well in the culture of the laboratories. The "alumni network" of former students and postdocs means there are university faculty and industrial researchers who maintain ties back to the labs they encountered earlier in their careers which they can draw upon when they need access to the specialized tools and people at the labs to solve the problems they are facing in academia or industry.

Universities and labs often work together through other mechanisms to solve challenging problems. A couple examples from Los Alamos, Bette Korber has been working with collaborators at Harvard and Duke Universities to develop an HIV vaccine. Much of this research has been funded by the National Institutes of Health and the Gates Foundation. The Los Alamos Weapons program has been working with universities in New Mexico, Texas A&M, and Montana State to develop programs that will train our next generation of weapons stewards. We also have an agreement with the University of Nebraska Medical Center to collaborate in areas of biomedical/biological research. These are just three examples of many that could be cited from across the 17-laboratory complex.

Question 2: We have a growing maintenance backlog across the national labs, and while it may be tempting to start new and build new capabilities at a new agency or build a new national lab, we would be better served by investing in and modernizing our existing labs.

a. What do you see as the greatest short- or long-term investment needs in the national lab system?

Our greatest needs at the laboratories are investments in our physical infrastructure and our human capital.

In the near-term, we should leverage the billions invested in constructing and equipping scientific user facilities and other research facilities by providing sufficient funding to support maximum operations. This will ensure that U.S. researchers in government, industry, and academia have access to scientific capabilities that are among the best in the world and to the teams of experts who can help them leverage those capabilities to conduct high-impact science. Maximizing operations will also enable research collaborations with universities, improve the ability and capacity of the laboratories to partner with industry on technology development and deployment, and train thousands of future scientists and engineers. Targeted investments will ensure technologies enter the marketplace, advancing solutions to our most challenging problems and keeping American businesses competitive, creating jobs, and driving economic growth. It is much more effective to first make sure existing facilities are utilized to their full potential by making sure they are adequately staffed and operating budgets support ongoing improvements in instrumentation to increase the number of users and scientific capabilities.

Both now and in the long-term, significant new federal investments in infrastructure and scientific instrumentation are needed to ensure that our national labs are safe, secure, and provide the nation with 21st century research facilities and equipment to address global threats, ensure American leadership in technologies and industries of the future, and attract and develop the best and brightest scientific workforce to meet these challenges. While DOE has made significant investments in its world-class experimental facilities to accommodate evolving science and technology mission needs, the infrastructure "backbone" of the national laboratories is aging and increasingly failing. The average age of lab facilities and related support infrastructure is nearly 40 years old. Modern, reliable general-purpose infrastructure – and the elimination of old, functionally obsolete, inefficient, and costly-to-maintain facilities through decontamination and decommissioning – is critical to the successful and efficient execution of DOE's missions both now and in the future. Other facilities also require significant recapitalization to procure and deploy modern, cutting-edge scientific instrumentation.

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Investing in our infrastructure will help us recruit and retain some of our country's best and brightest researchers. In many cases as much as 50 percent of laboratory staff is retirement eligible. The investment in our scientific tools, general infrastructure, and research areas will show the next generation that we are serious about providing the capabilities to deliver on research that will allow us to be competitive on the world stage.

The Department of Energy's Office of Science laid out a 20-year roadmap for scientific facilities in the mid 2000s that articulated a strategic for investment in new facilities and upgrades of existing facilities to ensure US science would have access to state-of-the-art tools. As we approach the 20-year anniversary of the roadmap the last few of these facilities investments is underway (including, for example, the APS Upgrade and the SNS Second Target Station). It is hence timely to consider what will be needed to secure the U.S. competitive position for the next 20 years.

The nation must also invest in high school and university programs that promote critical STEM programs. U.S. universities awarding masters degrees and PhDs in engineering report that over 50 percent of these graduates are from foreign countries. We must continue to find ways to encourage U.S. students to pursue STEM knowledge and skills, and let the best and brightest from around the world to study and stay in the U.S. after graduation if we are to compete on the world stage in the decades to come.

b. Do you know what the current maintenance backlog is across the labs?

The laboratories have identified roughly $30 billion worth of infrastructure projects that could be executed within the next 5-8 years. This does not include the total maintenance backlog across the NNSA weapons complex or longer-term projects that are planned but would begin execution outside that window.

Questions from Ranking Member John Barrasso

Question 1: Our national laboratories played an integral role in combating COVID-19. The national laboratories really delivered in our time of need. What enabled the labs to respond so quickly and effectively?

With world-leading expertise and capabilities in computational modeling, trace chemical and biosignature detection, situational modeling, structural biology, advanced manufacturing, engineering, bioscience, and biotechnology distributed across its 17 laboratories, the DOE responded to the COVID-19 Public Health Emergency by bringing its laboratories together as one focused team, and launched the National Virtual Biotechnology Laboratory (NVBL) in March of 2020. This team rapidly stood up 3- to 6-month research sprints to address critical needs: improving capabilities for and ensuring effective detection of infection; expediting discovery of therapeutic drugs, including antibodies and antivirals, to complement vaccine development; providing epidemiological and logistical support to Federal, state and local decision-makers to more accurately forecast disease transmission; addressing supply chain bottlenecks for PPE, test kits, and ventilators; and understanding fate and transport of the virus in buildings and public spaces to assist in reopening the economy. For example, studies at DOE's x-ray and neutron user facilities to determine the structure of virus proteins fed into studies that employed DOE's leadership computing user facilities to accelerate the molecular design of antibodies and antivirals that were used to treat infected individuals. Further, characterization tools at the DOE nanoscience research centers and light sources were used to rapidly optimize the performance of N95 facemask materials, speeding transfer of technologies to industry. In only six months, the team delivered major advances for combating the threats posed by COVID-19 by capitalizing on world-leading expertise, capabilities, and facilities across the DOE national laboratory complex and transferred technologies to industry that also resulted in the creation of nearly 1,000 new jobs.

Question 2: Please contrast the distinct missions of the Department of Energy and the National Science Foundation.

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The mission of the Department of Energy is to ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. Since their founding in the Manhattan Project, the DOE national laboratories have delivered those scientific advances and technology solutions for the nation, while balancing the need for open, collaborative science with the imperative of national security, economic security, and technological superiority. The DOE national laboratories are mission-driven research and development organizations that reside in an important space, with a long-term perspective and operating across the full spectrum from fundamental to applied research to the demonstration and deployment of technologies. This makes them complementary to both academia, which focuses on fundamental research and the advancement of knowledge, and industry, which is primarily concerned with the development and application of research outcomes in the near-term.

NSF, like DOE, is an essential component of the nation's innovation ecosystem and an important partner to the DOE and its national laboratories. NSF is the only federal agency charged with the promotion of scientific progress across all science and engineering disciplines. The research funded through its rigorous peer review process is vital to the public interest and has led to transformative discoveries that have reshaped our world. Through its sponsorship of cutting-edge, university-based research, NSF supports the education and training of the nation's scientists, engineers, and teachers and the next generation of new ideas.

Complementing these efforts, DOE assembles and nurtures multi-disciplinary teams of scientific experts to meet federal needs and address national priorities by attacking R&D challenges at scale. DOE does this by supporting university research, industrial partnerships, and a network of 17 national laboratories that are responsible for cutting-edge science and technology research and development. The national laboratories are also responsible for constructing and maintaining one-of-a-kind, world-class research capabilities that are leveraged broadly by over 36,000 university and industrial researchers every year.

National labs, universities, and industry comprise the U.S. innovation ecosystem, making coordination between DOE and NSF absolutely essential to leveraging each agency's respective strengths to maintain U.S. leadership in key technology areas. Because the whole of this ecosystem is greater than the sum of its parts, investments should be made in an integrated manner that supports all the parts of U.S. research and development ecosystem if the U.S. is to remain globally competitive. The NSF fosters a principal investigator driven, bottom-up, approach to R&D that prizes the individual creativity of academic groups. The DOE is a more mission driven, top-down enterprise focused on national priorities as articulated through Congress and the Administration.

Question 3: Our national laboratory system is highly regarded around the world. In your testimony, you mentioned that China is replicating this model. Can you elaborate? What are the implications here at home?

The U.S. has been benefiting from our National Labs since their establishment during the Manhattan Project. Innovation from the Manhattan Project and Cold War era propelled the U.S. to be the world leader in nearly every technological area for several decades.

Innovation in this era led to such things as nuclear power, satellite communications, medical imaging, supercomputing, advances in energy efficiency, and the human genome project. The U.S. dominated for decades in these fields and it led to the U.S. leading the world economy as we invented and manufactured the technology that economic advancements relied upon.

Other countries, like China, were watching. As they watched, they learned that co-locating multiple disciplines at one site — in the model of our national labs — and an integrated ecosystem of universities, national labs, and industry have shown the greatest success in innovation. Significantly increasing investment in their own domestic research capacity, combined with actions to leverage research and other proprietary information they have gained through illicit means, has enabled the Chinese to be competitive and in some cases lead the U.S. and the world in the development and deployment of technologies critical to industries of the future.

The Chinese effort has been motivated by the observation that while it was successful in establishing world leading scientific infrastructure, for example having multiple number 1 supercomputers on the Top 500 list, China was lagging in realizing the scientific benefits that should accrue from those investments. In benchmarking their results against other countries, the Chinese government came to recognize that successful exploitation of the scientific potential of marquee investments in synchrotrons, supercomputers, and

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neutron sources relied not just on the nameplate performance specifications but also on the fact that the facilities in the U.S. were embedded in National Labs that had scientific staff and programs focused on their application to major societal challenges. This led to the announcements in the mid 2010s of the intent to form "comprehensive national laboratories" by President Xi. This immediately triggered a competition amongst regional governments to become hosts for these labs, which were based on assembling multiple Institutes of the Chinese Academies of Sciences on newly constructed campuses in major centers. Under the Chinese model, regional governments were partners in the investments to stand up these new labs in Shanghai's Pudong district and in Beijing north of the Capital Airport. The local investments were motivated by the recognition that the National Labs would become engines for technology-based economic development.

As history has demonstrated, the country or countries that lead in innovation will reap the benefits of the resulting economic growth and enjoy a strategic advantage in security.

Questions from Senator James E. Risch

Question 1: There is a bill that is currently moving through a different committee in the Senate that would replicate much of the ongoing DOE research at the National Science Foundation. Redundant research can be beneficial, but creating a new entity at NSF to do essentially the same work being done at DOE does not strike me as the best use of taxpayer dollars. In addition, the national labs historically and currently do not qualify for NSF grants. If we want real, game-changing research and development, we must recognize the incredible contribution of the national labs and make sure they are a part of any Congressional effort to spur innovation. Do you have thoughts on ways that we could encourage collaboration across the research ecosystem to ensure we maintain U.S. leadership?

Comprised of universities, national labs, and industry, the U.S. innovation ecosystem is the envy of the world. NSF, universities, DOE national labs, and industry play specific and complementary roles, and in many areas these separate entities already collaborate. Mechanisms like institutes, centers, hubs, and research consortia have proven successful at facilitating collaboration across the ecosystem, including in the areas of quantum information science, bioenergy, high-performance computing, grid modernization, and advanced manufacturing, to name just a few.

I believe it will take balanced investments across all areas of this ecosystem if we are to remain competitive. Increasing U.S. investment in individual university and national lab researcher grants in key technology areas, maximal operations of existing scientific user facilities, cutting-edge tools and equipment at both universities and national labs, proven collaboration mechanisms, and innovative approaches to technology transfer and commercialization will require continued coordination between NSF and DOE and significantly improve collaboration among universities, national laboratories, and industry. The challenges that we face as a nation are complex and are not likely to be solved by one entity alone. The diversity of the U.S. innovation ecosystem is one of its greatest strengths.

Question 2: The DOE national labs are often referred to as the crown jewels of our country's research and development ecosystem. The labs have tackled some of the biggest challenges, achieved scientific breakthroughs, and created economic opportunity through their research and development efforts. This model has been incredibly successful. It is no surprise that other countries, including China, are investing significant resources into replicating our national lab system. Dr. Mason, as a Lab Director, what impact does China's push to develop state of the art facilities and capabilities have on our national lab system?

China is investing heavily in replicating our national laboratory model and creating an innovation ecosystem like we have in the U.S. They view these laboratories and this ecosystem as key to leading the world economy. They recognize that investing in research and

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innovation is the foundation of economic strength and technological superiority that will enable geopolitical power. For example, Russia and China are engaging in cutting-edge weapons research and developing new validation tools that are similar and possibly more powerful than U.S. capabilities. They are using these tools to develop newer, more unique, and more effective weapons systems. These tools could also lead them to have a greater understanding of how U.S. systems work. Not only does our economy rely upon continued investments in research and innovation to remain competitive, our national security does as well. Competition in science, as in all things, does push us to not be complacent and in that sense we welcome competition.

Question 3: DOE's national labs are home to unique tools and capabilities that are made available to researchers at the labs, universities, and in some cases internationally. Can you share how university researchers access these capabilities? Does the demand for these tools and capabilities outpace the availability?

There are several different ways in which researchers can access the unique tools and facilities and collaborate with scientists at the national laboratories, including through national user facilities, institutes and consortia, undergraduate and graduate student programs, and research agreements. DOE user facilities are often large, world-class facilities with unique instrumentation that are open and accessible to university, industry, and government scientists based on the merit of their research proposals. These major pieces of scientific infrastructure range from advanced supercomputers and particle accelerators to large neutron and x-ray light sources and specialized facilities for nanoscience and genomics, and are vital tools of scientific discovery. DOE and the national laboratories provide access not only to these major scientific tools but also to dedicated experts who help industry users and tens of thousands of researchers funded by NSF and other agencies conduct scientific experiments with these powerful tools.

These facilities are made available to the research community at no charge, provided the research is published in the open literature. For companies that wish to conduct proprietary research there is a full cost recovery model that allows them to access the facilities at their own expense and retain the results for their exclusive use. International researchers can also use the facilities provided the research will be shared through open publication and based on reciprocal access between countries for mutual benefit. All foreign user access to DOE facilities is also subject to review to ensure there are no concerns about sensitive research areas, export controls, or counterintelligence.

However, operations of these facilities are highly budget-constrained at the same time that they are in such high demand that they are already oversubscribed in most cases by a factor of two to five. Any significant increase in funding for NSF, NIH, or other federal science agencies would place further demand on these valuable tools. DOE would require a complementary and commensurate investment in the tools, capabilities, and staff support for these user facilities to enable a greater volume of high-impact research and development.

Questions from Senator Steve Daines

Question 1: Dr. Mason, our National Labs are at the forefront of important and advanced research in energy, nuclear, computing and other advanced technology. As we discuss ways to continue to promote important research, what tools does Congress need to consider to ensure that we are developing and commercializing the next generation of technology faster and better than our international competitors?

In general, there are ways that Congress could assist with promoting commercialization of lab research and lab-developed technologies. In addition to expanding or extending the impactful tools already available to the labs, Congress could authorize addition mechanisms to support, promote, and expedite technology commercialization so the U.S. can stay ahead of our international competitors.

Here are some ideas for improving and speeding the transfer of technology from the lab to the market from the experts responsible for these activities at the national labs:

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- Increase small business access to technical capabilities and expertise at the national labs via a permanent small business voucher fund;
- Establish a permanent tech assistance program to enable lab inventors, scientists, and engineers to help small businesses overcome technical challenges, commercialize a technology, or assist entrepreneurs who license laboratory-developed technologies;
- Expand and fund lab-embedded entrepreneur (LEEP) programs, and provide the national labs with greater flexibility to identify and manage conflicts of interest (COI) and meet COI requirements that may otherwise impede innovation, partnerships, and technology commercialization; and
- Expand the budget, scope, and application (e.g., to DOE Office of Science and NNSA) of the Technology Commercialization Fund established in EPACT of 2005, and change existing law to require a "cost share" (different investments by both parties) rather than a "cost match" (equal investment by both parties) to increase the opportunities for private sector partnerships to improve technology commercialization particularly by small businesses and startup that may not have the resources for full cost matching.

To overcome regulatory and bureaucratic barriers to and significantly expand opportunities for technology commercialization, DOE and the national labs should focus on streamlining lab and departmental business mechanisms in the following ways.

- Expedite foreign partner review, especially given the reviews that occur at labs on the foreign entities in question.
- Create a clear and uniform set of policies and procedures (regardless of funding sponsor) for DOE labs to assert copyright and establish ownership of software to expedite transfer and licensing of software tools created by the labs.
- Encourage greater use of Agreements to Commercialize Technology (ACT) by giving all labs (rather than only those that request it) the authority to enter into such agreements, adding another permanent tool to DOE's technology transfer "toolbox."
- Promote DOE program adoption and use of the "Access" CRADA mechanism, which allows a second or third lab to join another lab's Cooperative Research and Development Agreement (CRADA) with an industry partner without the need to renegotiate an entirely new multiparty CRADA. This would help put agreements into place with industry more quickly and thereby reach partnership goals faster.

Question 2: Dr. Mason, I strongly believe that innovation and American ingenuity is the key to reducing emissions while growing energy jobs and promoting energy security. Taxing or regulating industries out of existence only creates fewer jobs while putting the U.S. in a position where we have a less stable energy grid and we play a reduced role in international energy politics. While there are dozens of new technologies DOE has been involved in, I would like to highlight a few I think are key to success.

a. Renewable Diesel is a drop in fuel that is chemically similar to petroleum diesel but has ~~a~~ lower emission. A number of small refineries throughout the U.S. and in Montana are looking at investing in and producing renewable diesel. How can our National Labs work with refineries to spur more development of this low emission fuel?

The DOE-EERE Bioenergy Technologies Office has funded the Feedstock-Conversion Interface Consortium (FCIC). The FCIC is a collaboration of industry advisors and nine DOE National Laboratories, including Los Alamos, dedicated to the continuous and efficient operation of the U.S. biorefinery industry. The national labs are exploring research into how feedstock composition, structure, and behavior impact overall biorefinery performance. FCIC has established mechanisms to work with industry partners, such as biorefineries, on R&D projects to efficiently and cost-effectively produce renewable biodiesel and other renewable fuels.

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b. Hydropower is already the largest producer of renewable energy in the United States and it produces consistent, carbon free, baseload energy throughout the country and in much of western Montana. Unfortunately, when many people think of new 'green energy' they don't think of hydropower, however, there are lots of new technologies within the hydro space currently being developed. Specifically pumped-hydro storage, which is essentially massive natural batteries, and in-stream hydrokinetic power, which captures the power of traditional hydro without the need for the construction of dams. Montana is already a leader in pumped hydro-storage and should be a leader in in-stream hydrokinetic power. What are DOE and our National Labs doing to promote these two technologies?

Pumped storage hydropower and in-stream hydrokinetics are important technologies for the grid of the future. Pumped storage works as a giant water battery, enabling integration of new renewable energy onto the grid and creating a more resilient grid. In-stream hydrokinetic technologies hold great promise in a number of applications to provide environmentally sustainable power to communities. And it's the DOE's Water Power Technology Office (WPTO) that supports the research, development, and deployment of emerging technologies to advance next-generation pumped-storage hydropower and in-stream hydrokinetic power.

In partnership with a broad group of stakeholders, WPTO and the national laboratories support the advancement and deployment of pumped-storage hydropower through a range of efforts. In addition to the development, validation, and demonstration of novel technologies, WPTO supports research to clarify present and potential future market opportunities for pumped-storage hydropower for grid services, including long-duration energy storage. It also provides pumped-storage valuation through modeling and technical assistance, and research on regulatory and permitting opportunities, to empower decision-makers.

With respect to hydrokinetic power, WPTO and the national laboratories study and assess the in-stream resource potential to sustainably harness the power of rivers throughout the country (https://www.energy.gov/eere/water/marine-energy-resource-assessment-and-characterization#riverine [gcc02.safelinks.protection.outlook.com]). They also support the development of in-stream components, prototype systems, marine-ready materials, and manufacturing methods. As a result of these efforts, communities like Igiugig, Alaska have successfully demonstrated that they can reduce dependence on diesel (https://www.energy.gov/eere/water/articles/river-hydrokinetics-reduce-dependence-diesel-alaska [gcc02.safelinks.protection.outlook.com]) through the use of in-stream hydrokinetic power.

c. Advanced Nuclear Energy is the next generation of nuclear power and has the potential to produce stable, baseload, carbon free power throughout the United States, including Montana. Right now, the Montana Legislature is looking at converting a prematurely closed coal power plant to an advanced nuclear station. This proposal could provide high-paying jobs and baseload power in rural areas of Montana that desperately need it. What are DOE and the National Labs doing to work with states, like Montana, who are seeking to build and invest in advanced nuclear power?

Providing advice or consulting assistance to private companies can become tricky due to legal constraints. However, entities that are looking to pursue advanced nuclear projects may reach out to the Labs and craft a proposal to be funded by the Department of Energy through an open competition such as Funding Opportunity Announcement-1817 or through Gateway for Accelerated Innovation in Nuclear Energy (GAIN). Small companies, communities, and universities have taken advantage of GAIN vouchers to plan their projects. In New Mexico we are helping at least two companies establish their research facilities and develop their technology strategy.

In closing, any new project should pay careful attention not only to the excitement of new nuclear but also to financial risks. Laboratory staff can help. There are existing government voucher programs to enable partnership with the national laboratories.

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Questions from Chairman Joe Manchin III

Question 1: DOE and the national labs offer a successful model of bringing technologies to market, but there are ways to improve that model, including in new programs authorized by the Energy Act of 2020. One challenge is ensuring that the foundational research activities in the Office of Science are effectively communicated to both the public and private sectors.

a. Where do you see successful practices or needed opportunities to connect the Office of Science with the Applied Offices or other parts of DOE to improve the flow of research and development activities?

Answer a:

There are two most impactful practices to connect the Office of Science and the Applied offices. Note those connections are only needed on overlapping research areas. There are many overlapping areas, but there are many non-overlapping research areas.

i.) Create cross program research projects, where there is joint management and staffing of the effort. The Storage Grand Challenge is the most recent example, that has a management of the efforts from multiple DOE offices, including EERE, Office of Science and OTT. I would recommend Congress authorize more programs like that, and that would require DOE to set up those cross-program efforts.

ii.) Create cross-program review committees: As required under the last Office of Science re-authorization statute, DOE stood up a cross program coordination effort, which is named RTIC (Research and Technology Investment Committee). That committee identified many areas across the various programs that have overlap, and developed joint efforts, in areas such as STEM education, biology and batteries. Most of the efforts were developed and executed by the career staff. I would recommend these joint efforts through that committee or a similar one continue.

b. How do you see the Office of Technology Transitions or other parts of DOE aiding this process?

Answer b:

i. OTT has the unique ability scan and influence the entirety of the complex's technology. OTT plays a vital role in ensuring that a bridge exist between the Office of Science and Applied Offices. Additionally, the office can serve as a force multiplier by pinpointing services and providing support to all DOE offices with a singular commercialization focus.
ii. OTT's funding is small but unique from the Office of Science and Applied Offices of DOE. OTT can put funding towards reality inexpensive but needed activities related to commercialization. These include private sector engagement, business training for researchers and IP protection

activities. Preserving OTT's ability to fund these unique activities will continue to amplify the commercialization activities of DOE.

Questions from Ranking Member John Barrasso

Question 1: Please contrast the distinct missions of the Department of Energy and the National Science Foundation.

Answer 1:

In general NSF is a leading agency in broad basic science, discovery, and education support for the country. It covers a broad scope of the sciences, including social sciences. And supports education from K-12, on to university students, and principal investigators at research universities. It does have a few areas of mission driven work, including Antarctica operations, and astronomy. On general it is a leader in principal investigator research across the country. The focus of NSF funded research is open science and non-classified.

In general, DOE is focused on mission driven science at the National Labs and centers around the country on specific larger scale research. The missions are varied, with a mix of classified and open science efforts. Mission driven programs in general are split between energy, general science, and the defense R&D efforts. Examples in energy include new battery chemistries, new nuclear power technologies, grid technologies, and cyber security. In the science area, it includes materials, chemistry, quantum, high performance computing and artificial intelligence, fusion, and biology. And the three major missions in defense are nuclear weapons, non-proliferation, and Naval Reactors.

In addition, DOE does have smaller but material university and private company funding programs, focused on the areas of DOE expertise, include in energy and the science program areas of the department.

Finally, DOE has significant exposure to both classified and open science efforts, and many research areas have aspects of both open science and classified aspects, such as AI, quantum, and physics.

DOE as a result has more experience mission driven programs, that have a combined classified and open science aspects.

Question 2: There are times when it is appropriate for research results to be available to the public and other times when we must protect research results. Some research initiatives may produce results that fall into each category. During the hearing, you discussed the approaches taken to distinguish open and classified initiatives. However, there is also a need to protect commercial information when working with industry. Will you please discuss how the Department of Energy handles proprietary information, including intellectual property, in its collaborations with industry?

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Answer 2:

In general, there are three types of legal structures that are used by the National Labs when they work with industry: i). Intellectual Property Licensing, ii). Cooperative R&D Agreements ("CRADA's), and iii). Work for other agreements/Strategic Partnership Projects ("SPP's). Under each type of agreement, it is common to have confidentiality agreements as a part of the engagement between an private industry company, and a National Lab. It is quite easy and normal to have commercial-standard terms on proprietary information between a National Lab and a company.

Questions from Senator James E. Risch

Question 1: There is a bill that is currently moving through a different committee in the Senate that would replicate much of the ongoing DOE research at the National Science Foundation. Redundant research can be beneficial, but creating a new entity at NSF to do essentially the same work being done at DOE does not strike me as the best use of taxpayer dollars. In addition, the national labs historically and currently do not qualify for NSF grants. If we want real, game changing research and development, we must recognize the incredible contribution of the national labs and make sure they are a part of any Congressional effort to spur innovation. Do you have thoughts on ways that we could encourage collaboration across the research ecosystem to ensure we maintain US leadership?

Answer 1:

In research areas that would benefit from cross-agency collaboration, such as the technology being looked at in bills before the Senate and House, I would recommend setting up authorization specifics that are inclusive of the agencies that can contribute, make the agencies co-leads in the efforts (vs being excluded or a minor sub-contributor), define clearly their respective remits on the efforts, and finally require them to set up cross agency coordination and collaboration mechanisms.

A clear example of where this was done, and has been successfully implemented, is the National Quantum Initiative Act passed jointly by this committee and Senate Commerce. The authorities passed by this committee to advance quantum technologies with the National Quantum Initiative Act has been very successful at advancing development of those technologies, and I would recommend that some version of those authorities could be very useful to replicate in some of the current Innovation bill terms being reviewed now.

In particular, your committee identified that there were three major science agencies with history and expertise in the area of quantum technologies, namely NSF, DOE and Commerce (NIST). Your act set up a three-agency effort, each with its specific area of focus, with specific authorities. And your coordination with the committee of jurisdiction for NSF and Commerce, namely the Commerce Committee took more effort for the Senate, but led to a much better program.

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I would recommend any new Innovation bill look more like the NQIA, vs replicating capabilities that already exist at another agency.

Question 2: DOE's national labs are home to unique tools and capabilities that are made available to researchers at the labs, universities, and in some cases internationally. Can you share how university researchers access these capabilities? Does the demand for these tools and capabilities outpace the availability?

Answer 2:

Most of the facilities, including the very large facilities generally referred to as "user facilities" at the National Labs are available on a competitive basis to researchers. In general, each user facility, such as a light source, collider, etc., has a certain capacity, based on technical capacity and budget appropriated for operations. Most of the capacity is open for researchers from National Labs and universities, including internationally, to make proposals to use them for scientific research. Each user facility has a selection process to select the most scientifically impactful projects to use the limited capacity. In general, the user facilities get far more proposals than there is capacity for the proposals. For those researchers that conduct open science that is planned to be published, the costs in general are covered by DOE operational budget for open science. Some of the user facilities are used by industry, and they compensate the labs for those costs.

I would point out that similar user facilities in some other countries, in particular Japan and France, have more advanced programs to work with industry on research on their lab user facilities. Notably Spring-8 in Japan and Grenoble facilities in France have extensive public-private research using their facilities. I would recommend authorizing additional efforts on joint National Lab and private company research, like in Japan and France. This would accelerate Innovation impact in the economy.

Question from Senator Steve Daines

Question: Mr. Dabbar, as the former DOE Under Secretary for Science and now Chairman at Bohr Quantum Technologies, you have seen first-hand the importance of research and development of quantum technology, especially in the race against China. With my strong support this committee passed new authorities a few years ago for DOE research into quantum information sciences. How were those new authorities exercised under your leadership at DOE, and now that you are in the private sector, how does that research help you compete, grow and build jobs?

Answer:

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In particular, your committee identified that there were three major science agencies with history and expertise in the area, namely NSF, DOE and Commerce (NIST). Your act set up a three-agency effort, each with its specific area of focus, with specific authorities. And your coordination with the committee of jurisdiction for NSF and Commerce, namely the Commerce Committee took more effort for the Senate, but led to a much better program.

Since its enactment, NSF used its authorities to set up new university centered education and research programs. NIST set up a commercializing consortium with a very long list of participants from the commercial quantum sector.

DOE used its authorities to bid out and stand up the five NQI Centers, to focus on research of new science and technologies around quantum. One of the most important authorities you included was allowing DOE to take proposals from National Labs, universities, and the private sector. As a result, when DOE put out it direction for the proposals, it encouraged consortia bids that included parties from all the areas. DOE received many proposals, and at the end, the selected five centers each had participants of all three areas. A total of 69 entities are in the 5 centers, from 22 states and 2 allied countries (Italy and Canada). The private sector entities were quite diverse, including major companies and start-ups, and from the technology, manufacturing and finance sectors. And the participants contributed approximately $300 million of their own money and in kind. These outcomes were far in excess of our expectations, and showed the depth on interest in partnering around a national effort in quantum technologies, and well as a well-structured process by DOE.

This research effort is already accelerating technology development, and having private entities involved from the beginning is already generating specific commercialization prospects. It is a great start for the first year of the program.

Questions from Senator Lisa Murkowski

Question 1: During your four years as undersecretary for Science at the Department of Energy, you had the opportunity to see what worked at the Department and areas that could be improved. What reforms would you make at the Department of Energy to make the U.S. more globally competitive?

Answer 1:

First, I would develop additional specific technology areas to focus on and create focused technology development programs to drive them forward. Similar to the authorizing efforts for the National Quantum Initiative or the Storage Grand Challenge

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Second, I would require these technology efforts to have joint participants from national labs, academia, and the private sectors. Diversity of capabilities and ideas is critical. And having private sector participants from the start, vs trying to find commercialization partners after the research, if far more efficient and faster to drive American competitiveness.

I would also recommend several Office of Science and Office of Technology Transitions program changes:

A. I would recommend authorizing a National Lab Foundation, to facilitate commercializing, similar to NIH authorities.
B. Authorize National Labs to enter into working relationships with Venture Capital firms, to facilitate regular dialogue, review and possible commercialization of innovation. Similar to how many universities have started venture capital coordination efforts in recently.
C. Authorize programs to facilitate spin out of start ups by Principal Investigators at the National Labs. Including flexibility for splitting the Principal Investigator's time between a start up and lab employment, similar to how universities operate on this topic.
D. Authorize the Office of Science to allow joint public private research centers at the National Labs on specific new technologies, such as semiconductors, batteries, etc. Similar to how the Applied Offices and their labs currently do.
E. Increase the weighting of the annual lab reviews by their respective DOE offices on commercialization topics.
F. The coordination between the NNSA and OTT (rest of DOE) commercialization programs needs authorization to operate better. The semi-autonomous authorization terms for NNSA sometimes causes challenges on commercialization efforts. The NNSA labs are very successful at non-classified commercialization prospects and efforts. When I oversaw commercialization, we merged the two efforts at DOE, split between OTT and EERE. I would recommend amending the NNSA authorization to allow either i.) the NNSA non-classified technology transition effort report to OTT, or ii.) require the NNSA non-classified effort to coordinate with OTT, and authorize direction communication between the two offices that do not need to go through the NA-1 office.

<u>Question 2</u>: The Energy Act of 2020 established the Office of Technology Transitions and the Lab Partnering Service Pilot Program at the Department of Energy to improve the commercial impacts of research investments at DOE and strengthen partnerships between our National Labs and the private and public sector. Will this new office and program help enable DOE's research and development to move from the lab to market and support a more innovative ecosystem at DOE?

<u>Answer 2:</u>

A. Yes these new authorizations will help further commercialization. Various earlier versions of these programs were started by Secretaries Moniz, Perry, and Brouillette. The office is about six times larger than when Secretary Moniz started it (although it is still a small office compared to the research program offices), and the efforts at each of the seventeen National Laboratories on commercialization has also significantly increased. I would recommend further increased support for the office, so the investment in research continues to make more of a commercialization impact, and create an Appropriations line item for OTT in the DOE budget.

B. The Office needs the correct tools to accomplish the mission set forth in the Energy Act of 2020. The DOE recently commissioned a report, per congressional direction, from NAPA about the potential impact of a DOE Foundation. The tools available to non-profits to help move technologies beyond the authorizations of DOE or any government entity. I believe there is a bill to authorize this idea, and I would recommend including it in any Innovation bill.
C. The April 2019 NIST Return on Investment Green Paper highlighted the a few action items that can assist in this effort:
    a. Federal Laboratories could accelerate technology maturation by attracting private sector investment through Non-Profit Foundations.
    b. Recipients of Federal funding could benefit from a Limited Use of R&D Awards to enable intellectual property protection.
    c. Current requirements for Managing Conflicts of Interest that vary across agencies and lack flexibility pose challenges to build a more entrepreneurial R&D workforce.
D. The NIST Green Paper makes various recommendations for updating Bayh-Dole and Stephenson-Wydler Acts. I would recommend the Senate look at including those recommendations into an Innovation bill.

Question 3: In your testimony, you recommend that the Energy and Natural Resources Committee have direct responsibility and oversight in areas like oil and gas technologies. Can you expand on the potential areas that the Department of Energy could improve in, to support the research and development of oil and gas extraction methods that maximize the production while limiting the environmental footprint of development?

Answer 3:

I would recommend authorizing some new specific Office of Fossil Energy research programs in the areas of most interesting cutting-edge extraction technology, such as high performance computing and AI efforts for geology. And I would identify and create specific programs in the areas of environmental impact that DOE and National Lab have research expertise in. Such as water & ground contaminates research.

Question from Senator Mark Kelly

Question: What are your thoughts on how to best achieve the right balance between investing in manufacturing and R&D in the next generation semiconductors?

Answer:

Next generation semiconductor technology, including chip design, fabrication tool technologies, and chip manufacturing/fabrication, are critical areas that deserves additional effort. U.S. historical leadership in tool development and manufacturing has been eroding, and there are important economic and national security drivers to reverse that trend.

I would recommend that the federal government significantly increase support for those two areas, and balance this support between both.

I would recommend additional federal R&D support, with National Labs, academia, and private sector participants in joint R&D centers, on fabrication tool science and development. Setting up authorization for these "centers" to be bid out, and encourage joint submissions, would be a very good implantation policy, similar to the DOE NQIA R&D centers.

And I would recommend additional support for new manufacturing facilities, particularly focusing on facilities that would be built to manufacture the next-generation, most complicated and sensitive, semiconductors. This could be done through tax policy for investment, through "trusted foundry" contracts from DOD, or other mechanisms.

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Questions from Chairman Joe Manchin III

Question: China is winning the global race to invent and manufacture technologies that will allow for a lower carbon world. The U.S. is certainly behind, but we are also well positioned to compete in these global markets and bring these jobs and supply chains to our communities here at home.

a. How should DOE prioritize its tools to increase U.S. competitiveness in global energy markets?

DOE should set clear strategic objectives to drive the progress and priorities for developing clean energy technologies. DOE should be well resourced to invest in the full value chain of those technologies including basic and applied research, demonstration projects, and deployment incentives. DOE should also bolster its analysis of clean energy supply chain vulnerabilities and potential for US competitive advantage in key clean energy technologies. DOE should work closely with private industry and other government agencies to coordinate an approach to cultivating our competitive advantage in a given energy technology.

b. Are there particular efforts that are working well that deserve greater attention?

Efforts to build US supply chains and competitiveness in hydrogen and battery technology are particularly important and potentially advantageous from a competitiveness and security perspective.

Questions from Ranking Member John Barrasso

Question: In your testimony, you mention that the Department of Energy is an obvious choice to lead science and technology innovation. The National Science Foundation is our nation's leader for basic science and discovery research.

a. Do you believe it is important for the National Science Foundation to maintain a focus on basic science and discovery research?

Yes.

b. Do you agree that the Department of Energy should continue to have a leading role in applied science and technology innovation?

Yes.

Questions from Senator James E. Risch

Question 1: There is a bill that is currently moving through a different committee in the Senate that would replicate much of the ongoing DOE research at the National Science Foundation. Redundant research can be beneficial, but creating a new entity at NSF to do essentially the same work being done at DOE does not strike

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Questions for the Record Submitted to Ms. Sarah Ladislaw

me as the best use of taxpayer dollars. In addition, the national labs historically and currently do not qualify for NSF grants. If we want real, game changing research and development, we must recognize the incredible contribution of the national labs and make sure they are a part of any Congressional effort to spur innovation. Do you have thoughts on ways that we could encourage collaboration across the research ecosystem to ensure we maintain US leadership?

As I mentioned in my testimony, it is important for the US government to set clear strategic priorities for the development of clean energy technologies that are informed by a view of our national interest including climate goals, energy security priorities, and the global clean energy competitive landscape. Many government agencies and entities, including the national labs, are and should be engaged in supporting the development of different types of clean energy technologies and there are many programs designed to ensure that those efforts are mutually supportive. DOE is the most appropriate agency to establish the goals for clean energy technology development from a deployment standpoint – i.e. what are attributes most important for advancing the acceptable use of a given technology in the US economy and around the world that supports our national and global interests. They should work with other government agencies, including NSF, as well as the private sector through public private partnerships to understand the various roles and responsibilities each play in helping to meet those objectives.

Question 2: The DOE national labs are often referred to as the crown jewels of our country's research and development ecosystem. The labs have tackled some of the biggest challenges, achieved scientific breakthroughs, and created economic opportunity through their research and development efforts. This model has been incredibly successful. It is no surprise that other countries, including China, are investing significant resources into replicating our national lab system. Ms. Ladislaw, you have testified in front of this committee before about the significant investment by China into innovation capabilities – the investment has more than doubled in the last ten years. What are the potential ramifications of the US falling behind China in research capabilities?

The United States has long enjoyed a world class energy research and development enterprise spanning both the public and private sectors. These innovations improve economic, security, and environmental outcomes for the United States and countries around the world. They drive down the cost of energy and provide saving for households and consumers. They make our energy system safer and more secure – less vulnerable to attack and disruption – and the provide energy security by providing more supply, reducing demand through efficiency, and ensuring a diversity of available energy resources. The full value chain of energy innovation – from invention to deployment – provide benefits for the United States. While the United States is still home to some of the most innovative clean energy technologies under development, we have not kept pace with our ability to manufacture and deploy those technologies – which is an important part of the innovation value chain and without which the United State will become reliant on other countries for supply. Falling behind on energy innovation means the U.S. will have less ability to shape and benefit from the clean energy economy of the future.

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Questions from Chairman Joe Manchin III

Question 1: Over the past several decades, the most innovative technologies have come out of agencies that have worked together toward common goals, including DOD, NASA, NSF, and DOE, as well as their networks of national labs, defense labs, and academic and private partners.

a. Can you highlight the role DOE and the national labs have in technology development and commercialization, and how that contrasts with the role that NSF currently plays?

DOE and NSF have complementary roles in supporting technology innovation and development. NSF dollars tend to fund universities across a very wide array of topic areas, and are especially valuable in early-stage and basic science work, as well as funding the infrastructure universities need (e.g., the Graduate Research Fellowship Program). DOE does very important basic science in physics and other fields applicable to energy, expanding into topics like advanced computing and biology. DOE also has a full range of program offices, in addition to the ARPA-e program, intended to take ideas through early-stage technology development. From a commercial perspective, within the electricity industry, DOE is a go-to partner for technologies that are on their way to deployment.

b. How can these activities at DOE and the labs be improved?

One major challenge DOE has is converting its "tech transition" paradigm to one of effective commercial impact. Ideally, DOE and the labs would overhaul processes and success metrics to include specific commercial and impact goals. Reforms to programs and operations should enable faster, stronger partnerships between government-funded technology developers and industry. Concrete steps to improve commercialization prospects include additional funding and partnering mechanisms for the Office of Technology Transfer, standing up and funding a National Entrepreneurial Fellowship program, and doubling ARPA-E's funding.

Question 2: DOE is responsible for an extensive R&D enterprise that incubates groundbreaking scientific discoveries, all of which need to be commercialized with the help of private industry. DOE has decades of experience in developing public-private relationships that drive innovation in our country.

a. Why is it so important to include private industry in the research and development process?

Often, early-stage research and development is done without industry involvement. Success metrics for Principal Investigators include papers published, students graduated, conference awards won, etc. In that environment, some researchers are unique and design their work to have real-world impact through commercialization channels. Most researchers are not. While some "blue sky," curiosity-oriented research with uncertain commercial returns is valuable, far more of the work at DOE's labs and throughout the academic enterprise should be directed toward impact. Engaging early and often with industry, through the R&D process, would help shape more R&D outcomes to be viable in solving real-world problems. Companies can help frame discoveries in terms of their commercial

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potential, and can help make initial economic estimates that prioritize technologies and strategies with a higher probability of commercial success.

b. What are the critical tools used by DOE and the national labs to make these partnerships successful?

One positive advance DOE has made recently is in encouraging and requiring private sector participation in funding opportunities. While requirements for private sector cost share are NOT always helpful, because they often effectively exclude smaller companies that do not have the resources to provide them, encouraging private-public collaborations turns the R&D community toward consideration of commercial impact. DOE also holds meaningful convening authority, and has the capacity to bring industry and researchers together in producing robust analytic work that helps guide public and private investment.

Question 3: There is a clear connection between successful research and development programs, strong domestic manufacturing capacity, and equally effective technology commercialization.

a. How do you see efforts by DOE and the national labs, such as the Manufacturing Institutes under the Manufacturing USA program, helping to strengthen domestic manufacturing and supply chains?

It is critically important that the U.S. continues to retain manufacturing capacity and capabilities. The U.S. may not easily compete with other nations on manufacturing volumes or on labor prices, but we can and should lead the world with sustainable, high-tech manufacturing processes that in turn may enable us to lead on cost. The Manufacturing Institutes are a helpful step toward bolstering these types of manufacturing capabilities in the U.S.

b. What other models do you see as helpful to the private sector and effective for DOE and the national labs to adopt or improve?

Within the manufacturing category, DOE and the labs should focus on critical technologies and materials, and should remain directly focused on two goals: manufacturing that utilizes technology for cost reduction, and that is inherently sustainable. Global demand for sustainable products is going to increase, and the U.S. can lead in production. In addition, the Federal Government should consider an expanded focus on sustainable, technology-enabled mining practices, especially geared toward the extraction of critical materials.

Outside of manufacturing, DOE should support a national entrepreneurial fellowship: a demonstrated, critical tool for accelerating technologies into commercial relevance. In addition, the DOE laboratory user facility model, and programs like the Gateway for Accelerated Innovation in Nuclear, provide valuable resources for the private sector. More of these types of activities would benefit the entire U.S. innovation ecosystem.

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Questions from Ranking Member John Barrasso

Question 1: What makes the Department of Energy a preferred partner for private sector innovators?

The Department of Energy works harder than any other agency to partner with the private sector on technology innovation. DOE, through its formal convening and RFI processes, consults industry in the design of its programs and funding opportunities. In addition, many funding opportunities in recent years have included industry partnership requirements. These requirements encourage private/public collaboration, which in turn increases the probability that DOE-funded technologies will have real-world impact. For those reasons, while I was the Director of Technology Strategy at Exelon, my team pursued more funding opportunities with DOE than with any other state or federal funding agency.

Question 2:

a. Will you discuss why rapid increases in research funding, which may not be able to be maintained over a significant period of time, can be problematic for federal agencies as well as universities?

It is important to signal to federal agencies and universities what the longevity of funding increases will be. An increase in funding to any organization requires an increase in institutional capacity in order to carry it out. Large, short-term funding increases like those offered under the American Recovery and Reinvestment Act can have very beneficial effects in galvanizing "shovel-ready" projects, but they should be labeled as such so that the institutional impact of funding reductions will be minimal.

b. Will you please discuss approaches to innovation that could be implemented by the Department of Energy without requiring significant increases in funding?

DOE should overhaul and simplify its contracting and reporting practices, in order to encourage more meaningful private sector participation in its programs. DOE should set a goal that collaborative R&D contracts are signed within three months, and should minimize requirements for reporting within DOE-approved accounting systems.

In addition, DOE should overhaul the success metrics it applies to laboratory work. These should expand from papers published to include patents pursued and transferred, private sector follow-on funding attracted, and companies created. The degree to which these changes are desirable is different for each laboratory and each technology area, and should not be applied in a manner that stifles very early-stage scientific creativity. But new criteria that foster a cultural shift within laboratories and universities toward climate and economic impact will strengthen U.S. innovation and competitiveness.

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Question: There is a bill that is currently moving through a different committee in the Senate that would replicate much of the ongoing DOE research at the National Science Foundation. Redundant research can be beneficial, but creating a new entity at NSF to do essentially the same work being done at DOE does not strike me as the best use of taxpayer dollars. In addition, the national labs historically and currently do not qualify for NSF grants. If we want real, game changing research and development, we must recognize the incredible contribution of the national labs and make sure they are a part of any Congressional effort to spur innovation. Do you have thoughts on ways that we could encourage collaboration across the research ecosystem to ensure we maintain US leadership?

Collaboration is critical to advancing new technologies and to solving large, societal problems like climate change. Indeed, the silos across government agencies, programs within those agencies, and the entities that do R&D are one reason that we are slow in developing comprehensive and viable technology solutions. Congress could, at a minimum, require more collaboration among agencies and funding programs that seek to address similar problems. They should also focus government work on impact; i.e., on getting to deployment of technologies developed. Ideally, Congress would establish and fund new crosscutting initiatives that are focused on problem-solving, allowing the agencies additional mechanisms to work with a wider variety of actors and to partner much more easily with industry.

Questions from Senator Angus S. King, Jr.

Questions: In our conversation during the hearing, you noted that the barriers for moving products from the research phase to commercial markets vary significantly by technology. You also recommended that the DOE should shift away from looking at technology transfer as just a handoff to the private sector, but rather focus more holistically on technology impact. I've recently become aware of some of the gaps that exist when it comes to the commercialization metrics that DOE is required to collect and report, particularly when it comes to digital products. I have also heard that these metrics are reported only at the agency level, rather than by lab or by technology, limiting the usefulness of the data to policymakers.

Can you share your thoughts on current metrics of success or commercialization and how more comprehensive and disaggregated data could help us better understand and support technology impact and the commercialization pipeline out of our national laboratories?

Some metrics, including, for example, ARPA-E's tracking of follow-on funding across its recipient organizations, is very helpful. Indeed, it would be good to have more commercialization-relevant metrics applied across the DOE enterprise, including but not limited to patents granted, companies spun out, and industry collaborations completed. Specifically, it would be good to evaluate the degree to which private companies are successfully leveraging DOE resources as user facilities, and/or how much industry/government co-investment in specific projects (and especially demonstrations) is occurring. These metrics and evaluations will only be helpful if they are sufficiently granular, and reported at the lab level, or, more ideally, at the program and/or subject matter level within each lab. It is important, however, that these metrics be applied flexibly across laboratories and programs: not all programs or lab divisions are focused on commercialization, and nor should they be. But those that are intended for commercial impact should be measured accordingly.

Gathering these metrics in this way would be helpful for industry to understand where to plug in. More importantly, it is an important step toward making a cultural shift toward faster impact. More of the work done at the laboratories and across our academic enterprises should be directed toward real-world problem-solving, in order to meaningfully enhance U.S. competitiveness.

Based upon your experience, what are the obstacles in the present structure that limit the timely commercialization of products or technologies developed under the auspices of the national labs or other DOE research programs?

In my view, the development of new technologies should start with a purpose in mind. Too often, researchers have an idea or an approach that they are enamored of pursuing, regardless of the result – a “hammer in search of a nail.” If more technology development started by asking what problem a new approach or technology might solve, that would improve the rate at which our laboratory and academic infrastructure produces meaningful, impactful solutions. In addition to characterizing the problem, early work should include an appreciation for the competition (what else solves the problem?), the potential costs associated with developing and deploying the new technology, and the challenges inherent in the development pathway – especially those associated with commercialization. Getting more academics and laboratory researchers to start this way requires a cultural shift away from the success metrics associated with papers published.

Additional obstacles to commercialization of DOE-funded technologies include the challenging, onerous, and complicated contracting and agreement procedures associated with industry partnerships. It can take a year or more to sign a collaborative research agreement with the DOE, and compliance with DOE funding reporting mechanisms requires expertise and extensive accounting systems. Some very large companies have resources and appetite to wade through these processes, but only when the potential benefits are EXTREMELY high. Most companies do not. DOE needs to work more seamlessly and quickly with the private sector, and needs to update its policies with respect to intellectual property. Collaboration agreements and IP agreements should respect the contributions of the American taxpayer and protect DOE-developed IP accordingly, but should also reflect the fact that those same taxpayers benefit much more from commercialized products than they do from government ownership of IP.

Finally, DOE programs need to focus on later stages. ARPA-E’s establishing the SCALEUP program is an important step in that direction, recognizing that the commercialization gaps for its program participants are far too high even after completing ARPA-E projects. DOE program offices and the labs need to do more to fund large-scale demonstrations, collaboratively with industry. More funding should go toward scaling, investing, and demonstrating early deployment of new technologies, in a way that catalyzes follow-on investment.

Opinion: AI companies are enabling genocide in China
The Washington Post
Michael Chertoff and N. MacDonnell Ulsch
April 12, 2021

Michael Chertoff is executive chairman of the Chertoff Group, chair of Freedom House and a former secretary of homeland security. N. MacDonnell Ulsch is the founder of Ulsch Cyber Advisory, guest lecturer at the U.S. Military Academy and a Boston College research fellow.

The Chinese Communist Party's persecution of the Uyghur people will go down in history as one of the worst human rights tragedies of our time — not just for the abject horror of targeting a population of 11 million for genocide, but also for the advanced technologies that enabled it.

Like most Chinese citizens, the Uyghurs have long been under constant high-tech surveillance that tracks, analyzes and records their every move and scours their personal communications for evidence of dissent. Compounding this culture of surveillance is the evolution of artificial intelligence from a novelty designed to win games of chess against humans into a science now capable of facial recognition and individual profiling. The Uyghurs have lived in China since the 9th century, yet their persecution has been driven by 21st-century technology.

Beijing has vowed to lead the world in AI, and its documented use in the identification and detention of Uyghurs shows that the regime is getting there quickly. The implications of this campaign are dire. A new study from the Newlines Institute for Strategy and Policy offers "clear and convincing" evidence that the repression of Uyghurs goes beyond detention and political indoctrination to ethnic cleansing, not only through death in "internment camps" but also by means of forced abortions and mass sterilization.

The most alarming known application of AI in the Uyghurs' home region of Xinjiang is so-called predictive policing, a disturbing marriage of dogmatic ideology, advanced technology and utter disregard for due process and the rule of law. Predictive policing is not a purely Chinese phenomenon, but an increasingly global one. At its heart is a belief that AI has the potential to make our cities and communities safer by identifying social trends that enable early intervention by law enforcement. But that is not how predictive policing works in practice, and especially not in China.

The ministries of Public Security and State Security — the Chinese government's main law enforcement and intelligence organs, respectively — work hand in hand with state-owned enterprises specializing in surveillance technology, such as the defense manufacturer China Electronics Technology Group Corporation (CETC). As early as 2016, there were reports that the Chinese Communist Party had directed CETC to develop software that could aggregate and analyze data on individuals' jobs, hobbies, consumption habits and other social behaviors to predict terrorist acts before they occur, a concept best known from dystopian science fiction.

While CETC's targeting and analysis systems have been invaluable to the government's efforts to monitor and detain Uyghurs, Chinese president and Communist Party leader Xi Jinping is evidently also determined to tap into the cutting-edge AI research and development done in other countries such as the United States, Britain, Norway, France and India. In 2020, a Chinese investment firm acquired an equity stake in Jina AI, a German start-up that uses deep learning to conduct extensive, highly scalable audio, text and video searches. In 2016, China-based Ant Group acquired a U.S. biometric security company that uses images of the eye to authenticate mobile devices, although recent reports indicate that Ant might soon divest that acquisition in light of increasing U.S.-Chinese tensions.

These companies, and others already working with the Chinese government, must be held accountable for contributing to the Xi regime's ongoing human rights violations. The United States and its allies must respond to companies that enable this genocide by blocking export of AI-enabling technology or through imposed sanctions.

A failure by the United States and its allies to act could allow the Chinese party-state to continue to improve its repressive AI-based technology, persecuting religious and ethnic minorities, and exporting homegrown methods of repression even more aggressively than it does now. Such a scenario can and must be avoided.

One response is for the United States to organize a coordinated effort to restrain the Chinese government's ability to further develop AI for its predictive policing program — for example, by bolstering protections against intellectual property theft in this area, enacting punitive sanctions to discourage private technology companies from collaborating with Beijing, and publicly and forcefully decrying the complicity of such companies in the human rights catastrophe in Xinjiang.

To be successful, such an effort would need bipartisan support in Washington, to win cooperation from democratic partners around the world and to persuade the private sector through laws and regulations to act in its own long-term interests. Action on this scale is necessary and urgent to curb the Xi regime's worst authoritarian instincts and minimize the human cost of its oppressive rule.

April 9, 2021

The Honorable Joe Manchin, Chairman
Energy and Natural Resources Committee
U.S. Senate
Washington, D.C. 20510

The Honorable John Barrasso, Ranking Member
Energy and Natural Resources Committee
U.S. Senate
Washington, D.C. 20510

Comments on the Endless Frontier Act and further research & development investment, by all former Department of Energy ("DOE") Under Secretaries for Science and Science & Energy

Dear Chairman Manchin and Ranking Member Barrasso:

We write to add our support to that of former National Science Foundation ("NSF") Directors and National Science Board Chairs for the proposed Endless Frontier Act. We believe the additional federal investment in science, technology and innovation would lead to strengthened American economic and national security.

We would also like to acknowledge the proposed strong research bills from the House Science, Space & Technology Committee: the NSF for the Future Act and the Securing American Leadership in Science and Technology Act.

We thank your committee for its bi-partisan leadership in providing consistent and increasing support for the Department of Energy and the DOE National Laboratories over the last several years. That support has enabled U.S. leadership across many of the areas described in the Endless Frontier Act.

The proposed areas link the need for additional investment in research and development in several key areas to enhanced national strength in the areas of national security and the economy.

The Endless Frontier Act recognizes that the federal government can accelerate America's innovation by boosting fundamental research in universities, laboratories and the private sector in key industries and technologies of the future. The Act calls for additional support to driving applications in ten targeted areas:

1. Artificial intelligence and machine learning;
2. High performance computing, semiconductors, and advanced computer hardware;
3. Quantum computing and information systems;
4. Robotics, automation, and advanced manufacturing;
5. Natural or anthropogenic disaster prevention;
6. Advanced communications technology;
7. Biotechnology, genomics and synthetic biology;
8. Advanced energy technology;
9. Cybersecurity, data storage, and data management technologies; and
10. Materials science, engineering and exploration relevant to other focus areas.

The draft Act proposes larger roles for the NSF, and the Commerce Department, but no direct role for DOE.

Similarly, the House Science Committee proposed legislation also calls for increased support for research and development but includes DOE and other agencies in their proposals.

As former Under Secretaries of Science and Science & Energy, we support of the intent of these proposals, to further increase research and development, and importantly, to accelerate development of key technologies that will have large impacts on the economic well being and national security of the country.

We note that DOE has significant experience and successes in both driving discovery-to-applications and has provided significant leadership in most of the ten areas in the draft Endless Frontier Act. We therefore urge that the final bill include DOE leadership, along with Commerce and NSF, in the new efforts.

As you are very aware, DOE was stood up from the Manhattan Project and successor organizations, and as a result, mission-driven basic science has been at the core of DOE and the National Laboratories since their birth. They continue to embody that ethos today, supporting significant leaps in applied technologies that flowed from the decades of mission driven science. DOE teams are experts in driving discovery and applying it for energy, broad technologies, and national security.

A few highlights of the power of DOE basic research to lead to innovation and new technologies are:

- Most new energy technologies were developed in part by DOE supported funding and/or work at the National Laboratories, including nuclear power, solar (the Sunshot project), and enhanced oil & gas production techniques. Just recently DOE supported researchers won the Nobel prize in Chemistry for lithium-ion batteries, leading to revolutionary improvements for electric vehicles and grid scale battery deployment. Power plant efficiencies have been significantly improved over the last two decades. And DOE has the successful ARPA-E program already in the energy area (an effort proposed in the Endless Frontier Act).
- DOE-led global leadership in High Performance Computing has been maintained for decades – recent examples include the commissioning of the then global #1 and #2 Summit and Sierra supercomputers and the Exascale program, which will commission the next top three HPC's in the world.
- DOE is the Lead agency for the National Quantum Initiative, building on decades of work at the National Laboratories in high energy physics, computing and materials, as well as other collaborations with other agencies on quantum.
- DOE has a successful global leading AI effort, built on the foundation of global leadership in HPC.
- DOE provides cybersecurity and cyber operations leadership, both as the sector specific agency for the power sector, and well as support for national security missions.
- DOE has had a very important role in biotechnology and genomics, from the discovery of mRNA, to the founding of the Human Genome Initiative at Lawrence Berkeley, Lawrence Livermore and Los Alamos, the precursor of the Human Genome Project. Lawrence Berkeley was an early funder of Nobel-prize-winning work on gene editing by Dr. Jennifer Doudna, and her efforts were supported by several DOE National Laboratories' advanced Light Source user facilities.

In addition to DOE having clear leadership in many of these areas, the ability of DOE to manage both open science and classified applications concurrently will be very valuable for these proposed programs. The proposed programs are being discussed in the context of national security implications of these technologies, in particular with regards to China. DOE has a long history of managing many dual use technology developments, not just in the nuclear area. Given HPC, Quantum, AI, and most of the other areas proposed have significant classified aspects, DOE and the National Laboratories are best positioned to develop and manage programs to balance those areas.

Finally, while some of the proposals might allow the other agencies to select DOE proposals to fund, in our experience, that might minimize your committee's oversight role, and might run into challenges to execute that funding, depending on appropriations language.

As you consider this topic further within your committee and with other members more broadly in the Senate, we ask you to continue your support for the DOE and the National Laboratories, and find a role for continued DOE and National Laboratory leadership in these new programs.

Raymond L. Orbach

The Honorable Raymond L. Orbach
Former Under Secretary for Science
U.S. Department of Energy

Steven Koonin

The Honorable Steven Koonin
Former Under Secretary for Science
U.S. Department of Energy

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The Honorable Franklin Orr
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