American Energy Innovation Council

THE POWER OF INNOVATION

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BIPARTISAN POLICY CENTER

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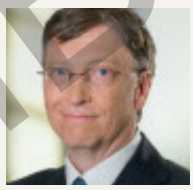

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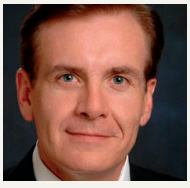

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American Energy Innovation Council

WHO WE ARE

The American Energy Innovation Council, originally formed in 2010, is a group of ten corporate leaders who share a common concern over America's insufficient commitment to energy innovation.* We speak as executives with broad-based success in innovation, who, in the course of our careers, have been called upon to overcome obstacles, seize opportunities, and make difficult decisions, all in the pursuit of building great American companies.

OUR MISSION

The mission of the American Energy Innovation Council is to foster strong economic growth, create jobs in new industries, and reestablish America's energy technology leadership through robust, public and private investments in the development of world-changing energy technologies.

The American Energy Innovation Council is a project of the Bipartisan Policy Center.

BIPARTISAN POLICY CENTER

ABOUT THE BIPARTISAN POLICY

The Bipartisan Policy Center is a non-profit organization that combines the best ideas from both parties to promote health, security, and opportunity for all Americans. BPC drives principled and politically viable policy solutions through the power of rigorous analysis, painstaking negotiation, and aggressive advocacy.

*Ursula Burns, CEO, Xerox; Jeff Immelt, Chairman and CEO, General Electric; and Tom Linebarger, Chairman and CEO, Cummins Inc., were founding members and serve in emeritus status.

LETTER FROM THE PRINCIPALS

In 2010, when the American Energy Innovation Council was formed, the premise was simple—as executives with experience leading and advising large companies in highly competitive industries, we understood the role that innovation plays in America's long-term competitiveness. We also recognized that access to clean, affordable, and reliable energy plays a foundational role in our nation's economic health and that the path we were on raised serious questions about our ability to maintain technological advantages that have been at the heart of America's success for as long as any of us could remember.

Much has changed in the intervening years—abundant natural gas has helped to transform our energy system, the costs of renewable energy systems have decreased dramatically, and improvements in end-use energy efficiency have saved consumers *billions* of dollars.[1] Global energy demand continues to rise while more than 20 leading nations have pledged to double their energy research and development budgets in partnership with private sector commitments to spend billions pursuing the next generation of low-carbon energy technologies.[2]

Yet in many respects, much has not changed at all. We still rely on many of the same energy technologies we have used for decades, modernizing energy infrastructure to better integrate new technologies continues to be a challenge, and a tight federal budget continues to lead to underinvestment in the types of innovation we need to revitalize our economy. This is especially problematic as key characteristics of the energy sector increase the importance of public investments that fill persistent gaps in the innovation cycle. Despite suggestions to the contrary, our experiences as CEOs and executives make clear that public and private investments both play necessary and complementary roles along the pathway to commercialization.

At times, it seems as though we have forgotten the ways that a commitment to innovation helped America become the world's dominant technological and economic power. Federal support for energy innovation has waned—even as our trading partners have increased their own commitments—despite clear evidence that targeted public investments have paid handsome dividends to taxpayers. As we focus on ways to boost our economy, there is an increasing recognition among Americans that the power of innovation can unite us in the common pursuit of prosperity.

The good news is that the United States still enjoys substantial advantages in the pursuit of energy innovation, including a world-class group of national laboratories, research universities

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and businesses. With the right mix of sophistication and vision, we can do more than capitalize on opportunities as they emerge—we can build on the best of American traditions and invent our own future.

We look forward to working with the administration and Congress to prioritize smart investments in our nation's energy future.

INTRODUCTION

Innovation has been the predominant driver of U.S. economic growth over the last century.[3] Scientific and technological innovation has given birth to new industries and the jobs that accompany them, helped maintain the competitiveness of a growing number of companies that rely on technology to succeed, and ultimately made American lives better. Throughout this history, the federal government has played a vital role in catalyzing innovation across a number of key strategic sectors such as defense, health, agriculture, energy, and information technology. In every instance, these sectors provide invaluable contributions to our nation while facing their own distinct set of challenges. This is especially true in the energy sector.

Access to reliable, affordable energy has such a profoundly positive impact on people's lives as to nearly defy calculation. Yet unlike many other technology sectors, the energy sector in particular has suffered from underinvestment in research and development (R&D) for a number of reasons. As a generally low-cost commodity, it is often difficult for an energy supplier to differentiate itself and charge a premium, the way products in other markets like communications hardware or biomedical technologies might. Energy infrastructure and technologies are also generally high cost and long lived, leading to large amounts of inertia and, in some cases, risk avoidance. Further complicating these challenges is the fact that energy markets are highly fragmented and often face a significant amount of regulatory fracturing and uncertainty.

These difficulties mean energy innovators are forced to cross not one, but two valleys of death before bringing a promising new technology to market. The first valley is technical—leaving the lab and creating a viable product where high technical and management risks compound the need for large amounts of patient capital. The second valley is commercial—even once a technology has been demonstrated to be viable, developing manufacturing processes and supply chains can have prodigious costs and projects are generally too far removed from commercialization to attract private investors. In both instances, targeted federal support can serve a critical role by reducing risks for promising technologies. In fact, such investments have a long and distinguished track record in providing important returns to the public in the form of economic growth, enhanced security, and environmental progress.

It is also important to note that the technology development process is not always linear. The consensus that innovation follows a linear process from basic to applied research then

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deployment has persisted in the post-WWII era. While research can obviously be purely basic or purely applied in nature, what may be less obvious is that a significant amount of research is a blend of the two. What's more, the flow of information across the innovation process is often not one-directional. The development of new technologies can open up entirely new fields of research that seek to answer fundamental questions of science sparked by observations in applied settings. That is not to argue against the value of differentiating among various types of research, but rather to encourage policymakers to understand the importance of interactions across various stages of a technology's development, as well as the role that cross- and interdisciplinary teams have to play in advancing the nation's scientific and technological interests.

A few decades ago, the United States found itself in the midst of an energy crisis. The response was a step change in our investment in energy research that helped lay the foundation for the energy renaissance we enjoy today. Further, as global demand for energy continues to rise, these investments have helped to put the United States in a position to expand its global leadership in the energy sector, while reaping the economic benefits that come with doing so. The global energy market attracted $1.8 trillion worth of investments in 2015 alone,[4] in what should be a clear signal to our leaders that advanced energy technologies represent a multi-trillion-dollar opportunity for American businesses and workers. We should embrace America's unique abilities to innovate as a way to revitalize our economy and enhance our security while helping American industry play a stronger role in providing clean, affordable, and reliable energy to the billions around the globe who currently lack it.

RECOMMENDATIONS

We believe there are a number of specific steps that the federal government can take to spur innovation in the energy sector, including the following six recommendations. These actions are critical to maximizing the potential of the nation's innovation capacity and realizing the economic, security and environmental benefits advanced energy technologies can provide.

RECOMMENDATION 1: Build on efforts to develop comprehensive assessments and strategic direction for the nation's energy sector.

The fundamental role that energy plays in the everyday lives of Americans means the need for a coordinated national energy strategy continues to be pressing. In 2011, the Department of Energy (DOE) released the first Quadrennial Technology Review (QTR), which provided a framework through which policymakers could better understand the variety of technical approaches available to solve the nation's energy challenges.[5] Through a robust public and government-wide engagement process, the QTR established priorities for DOE and outlined the respective roles of the public and private sectors in executing various strategic approaches.

Complementing this effort, in 2015 DOE released the first Quadrennial Energy Review (QER), which outlined ways to modernize our energy infrastructure.[6] As in the QTR, the QER sought out broad stakeholder input and a 2015 update of the QTR sought to highlight the most promising research, development, demonstration, and deployment opportunities for meeting the nation's energy needs.[7] The QER, which is conducted in installments to provide an opportunity to review specific aspects of our expansive energy system in greater depth, released a 2017 installment that focused on the electricity system.[8]

> "During my career, I had the opportunity to see first-hand the impact that effective public-private partnerships can have on the development of new technologies, products, and jobs. By harnessing the unique strengths and ambitions of each partner, we can set the stage for a prosperous future—but only if we make smart investments in that future."
>
> *- Norman Augustine, Retired Chairman and CEO, Lockheed Martin*

These efforts are extremely important to our ability to identify and measure progress toward national energy goals. Further, by identifying the nation's energy needs and opportunities, they provide a framework for developing priorities in public and private research. In essence, such efforts enable us to figure out where we, as a

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country, want to go and how to get there. In our experience as executives, we have repeatedly found that success is much more difficult in the absence of such a plan.

RECOMMENDATION 2: Invest $16 billion a year in advanced energy innovation.

In 2010, when we initially made this recommendation, the federal commitment to energy research, development, and demonstration was roughly 0.044 percent of the nation's energy bill.[a] By 2016, that number had climbed to just over 0.06 percent,[b] or $6.4 billion. Put in historical context, since 1987 energy research has decreased from 14.4 percent of federal R&D outlays to 5.3 percent by 2017.[9] Over the same time frame, health research has tripled in constant dollars and increased from 36 percent of federal R&D outlays to more than 50 percent in 2017. The private sector continues to be a driving force in developing and commercializing new energy technologies, but without public investments at key stages of the innovation cycle, many of these technologies will never attract private sector interest. Significant public underinvestment in energy innovation will have economic, security, and environmental consequences.

> "Innovation is at the heart of America's ability to lead in a complex and uncertain world. America's capacity to innovate can provide an unassailable advantage in energy security, national security, and economic security if we can demonstrate the vision and courage necessary to lead in rapidly evolving markets."
>
> *- Thomas A. Fanning, Chairman, President, and CEO, Southern Company*

Recent rankings suggest that the U.S. innovation system may be in danger of losing ground to other nations who are simply making greater commitments to innovation than we are. A 2016 Information Technology and Innovation Foundation study that ranked countries' contributions to global innovation found the United States to be the tenth most impactful nation.[10] The 2015 Global Innovation Index suggested that the United States has a supportive policy environment for innovation, ranking our nation fifth on this measure.[11] Our system of national laboratories and university research centers is without peer, consistently attracting and producing world-class researchers. If we look for the area where the United States has begun to consistently lag behind other nations, it is R&D spending relative

[a] According to EIA's Short Term Energy Outlook for February 2017, U.S. annual energy expenditures in 2010 were 8.1 percent of GDP. U.S. GDP for 2010 was $14.681 trillion (See, U.S. Department of Commerce, Bureau of Economic Analysis), meaning Americans spent $1.17 trillion on energy in 2010. The U.S. spent $5.1 billion on energy R&D in FY2010. See, American Energy Innovation Council. "A Business Plan for America's Energy Future." 2010. Available at: http://bpcaeic.wpengine.com/wp-content/uploads/2012/04/AEIC_The_Business_Plan_2010.pdf.

[b] According to EIA's Short Term Energy Outlook for February 2017, U.S. annual energy expenditures in 2016 were 5.4 percent of GDP. U.S. GDP for 2016 was $18.567 trillion (See, U.S. Dept of Commerce, Bureau of Economic Analysis), meaning Americans spent just over $1 trillion on energy in 2016. The U.S. spent $6.4 billion on energy R&D in FY2016 (See, U.S. Department of Energy).

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"An investment in a true energy transformation requires governments, research institutions, businesses, and private investors to work together. And it's hard to overstate how important this public commitment is."

- Bill Gates, Co-Chair, Bill and Melinda Gates Foundation

to the size of the economy. The United States still spends more on research than any other nation—although China is expected to surpass us in the mid-2020s if current trends hold.[12] But the United States also has the world's largest economy to support, which is why R&D intensity—R&D spending as a percentage of gross domestic product (GDP)—is the preferred metric for measuring a country's commitment to innovation. The United States ranks only 12th in energy R&D intensity.[13] This is a drag on our energy innovation ecosystem and an under-utilization of a significant engine of economic growth and opportunity.

Our recommendation would represent an increase in federal spending on energy R&D to 1.6 percent of U.S. energy sales. This would bring spending on energy innovation closer to, although still well short of, other advanced technology sectors. It would also reestablish American leadership on energy research in the face of growing competitive pressures from trading partners and more appropriately meet the scale of need for the capital-intensive energy sector.

RECOMMENDATION 3: Fund ARPA-E at $1 billion per year. At a minimum, ARPA-E should receive $300 million per year.

Originally authorized in The America COMPETES Act of 2007, The Advanced Research Projects Agency for Energy (ARPA-E) was modeled on the highly successful Defense Advanced Research Projects Agency. ARPA-E focuses on high-risk, high-impact projects across an array of potentially transformative technologies.

"Access to affordable, reliable energy is critical for a healthy and growing economy. Innovation has the potential to transform some of the challenges we face in the energy sector into opportunities, and it is important that we work together toward solutions."

- Thomas F. Farrell II, Chairman, President, and CEO, Dominion Resources Inc.

Initial funding for ARPA-E, as part of the American Recovery and Reinvestment Act program in 2009 was $400 million, yet in annual appropriations since 2011, funding for this important program has yet to reach the $300

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million we recommend as a minimum. Funding in fiscal year 2016 (FY2016) did reach $291 million and the agency has received significant bipartisan support in recent legislative activity[14] that could increase funding to $375 million by FY2019.

Since 2009, ARPA-E has invested in more than 580 breakthrough energy technology projects. As the first few rounds of awardees have begun to reach the growth stage where they could begin attracting private sector support, 74 ARPA-E projects have already secured more than $1.8 billion in follow-on, private sector funding across a portfolio of technologies, including: energy efficiency, energy storage, liquid transportation fuels, nuclear energy, wind, solar, hydrogen, and carbon capture and sequestration.

> **"Collaboration between key industries will be critical to creating a sustainable energy future for America. Together, we can build coalitions to advance the right policies and maximize the benefits of energy innovation."**
>
> *- Anthony F. Earley, Jr., Executive Chair of the Board, Pacific Gas and Electric Corporation*

ARPA-E's highly effective approach—a focus on "game-changing" technologies, strict performance metrics and an ability to jettison projects that do not meet milestones—has been central to growing, bipartisan support for the agency. The size of ARPA-E's budget only allows it to fund a small percentage of proposals. A $1 billion annual budget would more closely align with the agency's potential impact.

RECOMMENDATION 4: Support and expand new and innovative institutional arrangements such as the Energy Innovation Hubs, Energy Frontier Research Centers, and the Manufacturing USA program.

DOE's Energy Innovation Hubs, first established in 2010, focus on combining basic scientific research and engineering to make progress solving a particular challenge. Integrated teams with a variety of technical expertise from universities, industry, and government labs focus on the most persistent research obstacles faced within the energy sector. The Hubs invest in transformational, use-inspired research and play an invaluable role in the technology development cycle. For example, when attempting to scale up a technology, scientists and entrepreneurs can run into engineering challenges that require them to retreat several steps in the development process, which is both costly and time-consuming. Interdisciplinary teams at the Hubs can identify these issues earlier in the process, saving money and time while increasing the likelihood that a technology will successfully navigate these challenges. There are currently four Energy Innovation Hubs: The Consortium for Advanced

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Simulation of Light Water Reactors, The Joint Center for Artificial Photosynthesis, The Joint Center for Energy Storage Research, and The Critical Materials Institute.[15] A fifth hub was recently proposed, focusing on energy-water desalination, which would develop ways to decrease the cost and energy intensity of the desalination process.

DOE also supports vital research efforts at 36 Energy Frontier Research Centers (EFRCs). Directed through the Office of Science's Basic Energy Sciences program the EFRCs are awarded on a short-term basis (four to five years) on a competitive basis. EFRCs also utilize an interdisciplinary approach that includes universities, national laboratories, industry, and non-profits, but are focused on "grand challenges" in fundamental energy science. This is precisely the type of early stage, basic research for which federal support is best suited. At the start of the program, in 2009, there were 46 EFRCs, including 16 fully funded by the American Recovery and Reinvestment Act. Smart investments such as EFRCs are already having significant impact on our understanding of fundamental energy science.[16]

The National Network of Manufacturing Institutes, collectively named the Manufacturing USA program, was launched in 2012 and is an interagency effort operated by the Advanced Manufacturing National Program Office. Headquartered in the National Institute of Standards and Technology in the Department of Commerce, this program operates a partnership with the Department of Defense, DOE, NASA, The National Science Foundation, the Department of Education, and the Department of Agriculture.[17]

Other innovative programs like Cyclotron Road, Chain Reaction, and Innovation Crossroads focus on human capital, providing access to national labs for the nation's brightest entrepreneurial researchers who work alongside government researchers. Awards are highly competitive and designed to support high-impact technologies that are not far enough along in the development cycle to attract private investment. An added benefit of this innovative institutional arrangement is the cross-pollination of scientific and business perspectives that allows each to better understand central challenges and needs that inform their work.

"Today, scientists and entrepreneurs all over the world are racing to develop the next generation of energy technologies. If America is going to maintain the competitive advantages that have driven our success for decades, we have to be willing to invest in the people who are working to invent the future."

- John Doerr, Partner, Kleiner Perkins Claufield & Byers

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These programs represent a concerted effort to better utilize limited federal resources to fill critical gaps in the energy innovation ecosystem. Such efforts have already shown significant promise and policymakers should maintain or even expand these programs as they enhance the nation's capacity for innovation in energy.

> "Research and development has been the driving force behind cleaner, safer, more reliable, and affordable energy in the U.S. for decades. Constructive partnerships between the public and private sectors in energy innovation have been especially successful, leading to vast economic, environmental and security benefits, creating jobs, and boosting virtually every facet of our economy."
>
> *- Chad Holliday, Retired Chairman and CEO, Dupont*

RECOMMENDATION 5: Make the Department of Energy work smarter—along the ARPA-E model where appropriate.

Many of the best practices at ARPA-E could be implemented to improve the performance of DOE's technology offices. These include reorganizing by sectors (for example, transportation, electric power, buildings, etc.) instead of technologies—which can create silos; instituting aggressive milestones for continued project funding; and focusing on transformative technologies instead of incremental advances or deployment activities which are more likely to receive support from the private sector.

Some research conducted at DOE, especially within the Office of Science, is not well-suited to the ARPA-E model. Undirected, fundamental research plays a critical role in our nation's research portfolio and approaches like aggressive stage-gating would be counterproductive in that setting. Importantly, research that seeks to improve our fundamental scientific understanding and does not have a commercial application produces a critical public good in the form of expanded knowledge. A smart approach that fosters accountability and seeks to fill gaps in the innovation cycle that the private sector cannot or will not invest in, is the best use of limited federal funds.

DOE is charged with the significant task of overseeing and managing a sprawling research network and national security mission. A number of reforms have already been implemented that have made the Department better at fulfilling its mission. For example, the Office of Energy Efficiency and Renewable Energy has already begun implementing many of these ARPA-E style

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"Widespread public sector investment in basic energy technology is critical to complement private investment and drive long-term economic growth in America and globally. With new energy markets only set to grow, technological breakthroughs can generate enormous economic dividends while providing the lower cost, cleaner energy the world needs."

- Mike Graff, Chairman and CEO, American Air Liquide Holdings, Inc.

reforms. DOE's network of national labs is a world-class set of institutions that have made enormous contributions to our nation. Targeted and judicious reforms can make an already valuable public asset even more effective.

RECOMMENDATION 6: Establish a New Energy Challenge Program for high-impact pilot projects.

Many important energy technology options face greater obstacles to development, particularly on cost and risk bases. Advanced nuclear power and carbon capture, utilization and storage (CCUS) provide examples of essential technologies that face unique challenges, even within the energy sector. Without a significant commitment to pursuing these technology options, they will not thrive in the United States and opportunities for unique export opportunities worldwide will be lost. This undesirable outcome would mean ceding American leadership in key technologies to trading partners and competitors who are actively pursuing them. This recognition is at the heart of the AEIC recommendation for a New Energy Challenge Program.[18]

America's energy innovation ecosystem currently lacks a mechanism to enable the building, testing, and refinement of large-scale technologies such as CCUS. As we have noted, many of the energy technologies that require demonstration assistance are too big, expensive, or risky to secure necessary support from the private sector. We need to address the structural challenges inhibiting the progress of important and potentially transformative projects through the second valley of death.

"American businesses, especially manufacturers, must innovate to realize their potential, revitalize our nation's economy, and spur an energy transformation. Public-private partnerships are the bedrock of innovation, creating a foundation for success in the worldwide economy."

- Mark Burns, President, Gulfstream Aerospace Corporation

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The New Energy Challenge Program, by accelerating advanced energy technologies to commercial or near-commercial scale, would explicitly deal with those obstacles. It would focus on high-impact energy projects, including those with large system sizes, and would concentrate on the transition from pre-commercial, scalable energy systems to integrated, full-size system tests. The New Energy Challenge Program would draw on a broad range of expert perspectives and a set of financial, technical and management tools, with two main tasks: (1) to create detailed technology commercialization roadmaps for priority technologies as well as particular demonstration projects; and (2) to commission, finance, and build first-of-kind commercial-scale advanced energy facilities.

"Ingenuity and innovation have always been the foundation of American prosperity. Now is the time to lay the long-term foundation for the next generation of energy technologies. "

- Neal Blue, Chairman and CEO, General Atomics

We recommend the New Energy Challenge Program be funded with a single appropriation of $20 billion over ten years. This publicly owned, private corporation would employ a competitive selection process and cost-sharing to identify the strongest private partnerships. The program should have the ability to utilize a variety of financial tools but should prioritize direct equity investments. The New Energy Challenge Program is designed to unleash significant private capital in the development of high-impact technologies over the next half century.

Importantly, this program will not pick winners and losers. Project selection would be designed to test multiple technology pathways, pursuing demonstrations of the most promising options. For example, a variety of competing designs for advanced nuclear projects, each using vastly different approaches such as fuel cycles, would be able to apply for the program. Pursuing promising technologies in a non-prescriptive, highly competitive environment is key to effectively meeting national priorities.

In the end, public support for energy innovation is not only necessary, but creates benefits that far exceed the investments we recommend. If acted upon, these recommendations have the potential to significantly boost the nation's innovation capacity. Creating the next generation of advanced energy technologies in the United States will create jobs, enhance the security, and resilience of our energy system and pay geopolitical dividends as well. Our recommendations are meant to address obstacles to innovation in the energy sector in ways that maximize limited federal resources. In a forthcoming, expanded report, we will outline these hurdles and the impact that smart federal investments have on the everyday lives of Americans.

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