Written Testimony
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Chairman Murkowski, Ranking Member Manchin, and members of the Committee, thank you for the opportunity to join this critical discussion on the key role of innovation in our energy and economic future.

My testimony will focus on the imperative to raise our nation's ambition and commitment to energy innovation, and how this Committee can help overcome political obstacles to ensure an effective innovation agenda.

Propelling Economic Growth

Innovation is the core of America's economic strength and future prosperity. Indeed, at least 50 percent of the nation's annual GDP growth can be traced to increases in innovation.[1] While our nation must substantially increase its commitment and ambition to energy innovation, we have a sound foundation to build upon. Much of the energy abundance we enjoy today can be traced to our nation's unparalleled research and development (R&D) infrastructure. Today's shale gas boom can trace its history to industry-led research and demonstration initiatives funded by the U.S. Department of Energy (DOE), such as seismic mapping, horizontal drilling, and advanced drill bit technology developed during the 1970s. R&D carried out at the National Renewable Energy Laboratory (NREL) has enabled wind and solar energy production to quadruple[2] over the past decade while costs for these technologies have been cut nearly in half. Building on basic and applied atomic research conducted during the Manhattan

[1] Recognizing the importance of energy innovation to long-term economic growth and competitiveness, BPC convened a group of top business leaders who formed the American Energy Innovation Council (AEIC) (http://americanenergyinnovation.org/) in 2010 to support strong federal investments in energy R&D. The Council has published numerous reports, white papers, and case studies demonstrating these connections, and is in firm agreement that targeted and increased federal investments in energy R&D are crucial to bolstering America's long-term economic health and competitiveness.

[2] U.S. Energy Information Administration. "Electric Power Monthly – Table 1.1.A. Net Generation from Renewable Sources: Total (All Sectors), 2008 – May 2018." July 2018. Available at: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a

Project, the U.S. government began developing peaceful applications of nuclear technology following the end of World War II. The federal government built the first nuclear reactor[3] in the 1950s before transferring the commercial development of the technology to the private sector—and in doing so laid the bedrock for the modern nuclear energy industry, which contributed $60 billion[4] to U.S. GDP in 2015 and today supplies one-fifth of U.S. electricity and nearly three-fifths[5] of America's carbon-free electricity.

In addition to these often-cited marquee achievements, there is an ongoing and important role for public and private collaboration to improve the performance of our nation's energy systems. I have the privilege of serving on the National Petroleum Council (NPC) study on Oil and Gas Transportation Infrastructure.[6] Part of our focus is on how advances and deployment of new technology can improve the safety and environmental performance of our country's existing and future oil and gas infrastructure. Cooperation between public and private resources will be essential for all stages of deployment, from basic research to updating regulations to incorporate new methods of compliance. I hope this Committee will make time to explore the NPC conclusions when they are finalized in October. Corporations also can help advance innovative energy technologies through corporate power procurement practices. We have seen great success in business's ability to spur the development of renewables through power purchase agreements. We are now seeing businesses, such as Google, beginning to explore how to build on this successful model to procure 24/7 clean energy.[7]

Federal investment in energy R&D has a high return on investment. Recently, DOE found that federal investments in building efficiency R&D from 1976 to 2015 yielded energy savings of nearly $22 billion[8]

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[3] Mark Berkman and Dean Murphy. "The Nuclear Industry's Contribution to the U.S. Economy." The Brattle Group. July 2015. Available at: http://files.brattle.com/files/7629_the_nuclear_industry's_contribution_to_the_u.s._economy.pdf.

[4] U.S. Energy Information Administration. "What is U.S. Electricity Generation by Energy Source?" Updated March 7, 2018. Available at: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.

[5] U.S. Energy Information Administration. "U.S. Energy-Related Carbon Dioxide Emissions, 2016." October 2017. Available at: https://www.eia.gov/environment/emissions/carbon/.

[6] National Petroleum Council. "Energy Secretary Requests National Petroleum Council Advice on Two Major Topics." Press Release, September 27, 2017. Available at: https://www.npc.org/NPC-press_release-127th_mtg-092717.pdf

[7] Google. "Moving toward 24x7 Carbon-Free Energy at Google Data Centers: Progress and Insights." October, 2018. Available at: https://static.googleusercontent.com/media/www.google.com/en//green/pdf/achieving-100-renewable-energy-purchasing-goal.pdf

[8] Department of Energy. "Benefit-Cost Evaluation of U.S. Department of Energy Investment in HVAC, Water Heating, and Appliance Technologies." September 2017. Available at: https://www.energy.gov/sites/prod/files/2017/09/f36/DOE-EERE-BTO-HVAC_Water%20Heating_Appliances%202017%20Impact%20Evaluation%20Final.pdf

for consumers, achieving a benefit-to-cost ratio from 20-to-1 to 66-to-1. Similarly, public investments in high-efficiency diesel engines of $931 million between 1986 and 2007 were shown to generate $70 billion[9] in economic benefits, a return of $70 for every federal dollar invested. The National Academies of Science, Engineering, and Medicine found that DOE investments in energy efficiency R&D between 1978 and 2000 generated a return of roughly $20 for every dollar invested[10], while fossil energy R&D programs between 1986 and 2000 received $4.5 billion in funding but generated $7.4 billion[11] in economic benefits to the United States.

Late-stage R&D initiatives funded by DOE have also generated significant benefits to the United States. Seventy-five percent[12] of domestic coal-fired power plants employ technology with roots in DOE's Clean Coal Technology Demonstration program and the newly operational Petra Nova[13] carbon capture project in Texas was given critical support through a grant from DOE's Clean Coal Power Initiative. In addition, late-stage research and testing supported by DOE has continued to drive down the costs of deployed renewable energy technologies to make them cost-competitive with incumbent generation technologies.

Fostering International Competitiveness

<u>Increased public and private commitment to energy innovation is needed if we are to sustain U.S. global energy dominance</u>. Due to the remarkable technological advances in oil and gas production, the United States will become a net energy exporter next year.[14] Total energy investment worldwide was over $1.7 trillion[15] in 2016, accounting for 2.2 percent of global GDP. The United States must strive to

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[9] Jeffrey Rissman and Hallie Kennan. "Case Study: Advanced Diesel Engines." American Energy Innovation Council. March 2013. Available at: http://bpcaeic.wpengine.com/wp-content/uploads/2013/03/Case-Diesel-Engines.pdf

[10] National Academy of Science. "Energy Research at DOE: Was it Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000." 2001. Available at: http://www.nap.edu/download/10165

[11] Ibid.

[12] Department of Energy. "Fossil Energy Research Benefits." Accessed August 18, 2018. Available at: https://www.energy.gov/sites/prod/files/cct_factcard.pdf

[13] Department of Energy. "Clean Coal Power Initiative." Accessed August 18, 2018. Available at: https://www.netl.doe.gov/research/coal/large-scale-demonstrations/clean-coal-power-initiative

[14] U.S. Energy Information Administration. "Annual Energy Outlook 2019." January 2019. Available at: https://www.eia.gov/outlooks/aeo/

[15] International Energy Agency. "World Energy Investment 2017." July 2017. Available at: https://www.iea.org/publications/wei2017/

achieve a similarly dominant position in developing and exporting the efficient, and lower-carbon energy technologies required to meet the world's growing demand for clean energy.

China has become one of the largest[16] spenders on energy R&D as a share of GDP, and the United States now trails 12 other nations in the amount of public dollars invested in energy R&D relative to GDP. In our market economy, decisions to develop and commercialize new technologies must be driven by corporations deploying private capital. However, it must be recognized that the energy sector is uniquely challenged by the high costs of technology development and the difficulty companies face in recouping these investments directly or quickly. This dynamic is revealed in the fact that private energy sector R&D investments are just 0.3 percent[17] of revenues, compared to nearly 20 percent in pharmaceuticals,[18] 10.6 percent in electronics, and 7.6 percent in aerospace.[19] To compete in the global marketplace, U.S. technology policy must combine increased direct federal investment and incentives to encourage and reward private resource commitments.

Confronting Climate Change

The country needs a "Green True Deal," one that is anchored in innovation and designed to cushion the economic impacts and worker dislocations that are inevitable in the transition to a low-carbon economy.[20] Recent domestic[21] and international[22] assessments of climate change reinforce three fundamental findings:

[16] International Energy Agency. "World Energy Investment 2017." July 2017. Available at: https://www.iea.org/publications/wei2017/

[17] Industrial Research Institute. "2016 Global R&D Funding Forecast." 2016. Available at: https://www.iriweb.org/sites/default/files/2016GlobalR%26DFundingForecast_2.pdf

[18] PhRMA. "2018 PhRMA Annual Membership Survey." July 2018. Available at: http://phrma-docs.phrma.org/sites/default/files/pdf/biopharmaceutical-industry-profile.pdf

[19] National Science Foundation. "Science & Engineering Indicators 2018." January 2018. Available at: https://www.nsf.gov/statistics/2016/nsb20161/uploads/1/nsb20161.pdf

[20] Jason Grumet. "It's time for a Green 'True' Deal." Roll Call, February 4th, 2019. Available at: http://www.rollcall.com/news/opinion/time-green-true-deal-progressive-environment-climate-change

[21] U.S. Global Change Research Program. "Fourth National Climate Assessment." November 2018. Available at: https://nca2018.globalchange.gov/

[22] United Nations Intergovernmental Panel on Climate Change (IPCC). *Special Report: Global Warming of 1.5C*. 2018. https://www.ipcc.ch/sr15/

1. On the current trajectory, climate change will create unacceptable economic and social costs in the United States and around the globe.
2. The United States and other developed nations must achieve net-zero carbon emissions by mid-century to avoid the worst effects of climate change.
3. We do not presently have the technological capacity to decarbonize the domestic or global economy in this timeframe.

Over the next 20 years, global energy demand is projected to rise by 30 percent.[23] Across the globe today, there are as many people who lack access to electricity as there were when Edison commercialized the light bulb in 1882. The solution to climate change must accommodate the reality that billions of additional people must be provided with access to affordable and reliable energy services while we simultaneously eliminate carbon from the energy sector.

Here in the United States, millions of Americans' livelihoods and the economies of thousands of communities are directly linked to existing energy production. Moreover, millions of Americans are living paycheck to paycheck and do not have the luxury of buying a Tesla charged by community-solar microgrids. The hard truth is that proposals to achieve near-term decarbonization with existing technology—like moving to a fossil fuel free economy in the next 10 years—are technologically and economically infeasible. While presumably well-intended, these proposals distract from the evidence-based debate that is the predicate for real progress. The stakes are very high. Failure to decarbonize our energy system over the next 30 years will impose profound economic and social disruption on the next generation. We have no time to waste.

No one on this panel wants to impose economic hardship on millions of Americans today and no one on this panel wants to condemn future generations to diminished opportunity and reduced quality of life. The question then is this: What is preventing us from unleashing the awesome power of American ingenuity to create economically viable low-carbon energy solutions?

Overcoming Political Barriers to Innovation

<u>Effective innovation requires clear and realistic national goals, a relatively stable policy environment, and a culture that is resilient against occasional failure.</u> These conditions are not easily established in a closely divided democracy, and they are almost impossible to achieve when the Congress is not broadly united in a shared purpose.

[23] International Energy Agency. "World Energy Outlook 2017." November 2017. Available at: https://www.iea.org/weo2017/

The obligation to engage minority views and the commitment to value nation above party are historic strengths of our political system. These foundational features have led to national consensus and resilient public policy. It is remarkable what our nation has achieved when we commit to a broadly shared goal. The analogy to the moonshot is overused, but there is one insight that is often overlooked. Before our space program was a historic success, it suffered horrific failures. On January 27, 1967—six years into the space program—a fire erupted on the launch pad, killing astronauts Gus Grissom, Ed White, and Roger Chaffee. Our Congress did not turn on itself, restrict NASA program funding, or filibuster budgets. Instead, 18 months later, we held our breath and sent three more astronauts into space. Ten months after that, Neil Armstrong set foot on the moon.

Congress should never tolerate mismanagement in our innovation programs and must be vigilant to ensure that DOE is well-designed for success. But our nation cannot achieve great things absent a shared sense of purpose that carries us through when the going gets tough. While there is broad bipartisan support in Congress for promoting energy security and economic competitiveness, the absence of any shared vision about whether and how to address climate change is an intractable barrier to effective energy innovation policy.

Recent technical analysis by the Intergovernmental Panel on Climate Change and others has helped to reveal the urgency of the climate challenge, the inadequacy of existing solutions, and the need to prioritize substance and science over cultural preferences on the left and right. This Committee has an opportunity to take a critical step forward by clearly rejecting the false arguments that continue to feed division and dysfunction in our energy policy. If this Committee could agree that climate change is a critical challenge and agree that we cannot eliminate fossil fuels or achieve 100 percent renewable power in the next decade, it could then begin to develop a truly effective innovation agenda.

As a next step, the Committee should establish some clear and compelling goals. I do not pretend to know precisely what they are, but to my mind there are five technology pathways that have the potential to reconcile our economic and ecological imperatives. They are: 1) advanced energy storage; 2) advanced nuclear power; 3) carbon capture, utilization, and storage for coal and natural gas; 4) low-carbon transportation fuels, such as hydrogen and electrification; and 5) direct air capture technologies that remove carbon dioxide from the ambient air.[24] If none of these technologies are price competitive

[24] Carbon removal is a promising breakthrough technology where greater research and development is needed. Carbon removal encompasses a suite of land-based and technological approaches that remove already-emitted carbon dioxide directly from the atmosphere. Importantly, all pathways that limit warming to 1.5 degrees Celsius in the IPCC Special Report rely on some form of carbon removal. The 2018 National Academies report on negative emission technologies agrees that fundamentally new carbon removal options

and massively deployed in the next 30 years, I am not optimistic about the future. If all are successfully commercialized, we will dramatically strengthen our economy while literally saving the world. With some reasonable combination of success and failure, I am confident that we can provide a better future for our children, which has been our tradition for the past 10,000 generations.

As we strive to invent new technologies, it is essential that this Committee lead the Congress to recognize that we cannot accelerate the future by messing up the present. We must support the critical near-term investments in natural gas infrastructure, energy efficiency, renewables, and existing nuclear facilities—all of which are necessary to sustain our economic might and buy time for our innovation agenda to succeed.

The clean innovation agenda already enjoys considerable bipartisan support. Last year, Congress passed the Nuclear Energy Innovation Capabilities Act, which eliminates some of the financial and technological barriers standing in the way of nuclear innovation. Congress also examined the Nuclear

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will be needed to avert dangerous temperature rise and articulates the need for a multi-billion dollar federal R&D program across a portfolio of carbon removal technologies.

One of these approaches - direct air capture and storage - has nearly unlimited CO_2 removal capacity and is already operating successfully at pilot scale here in the United States. While a handful of companies around the world - including Carbon Engineering in Canada, Global Thermostat in the United States, and Climeworks in the European Union - have demonstrated that direct air capture technology works, efficiency and cost must be improved for it to be deployed more broadly.

In addition to carbon removal, carbon capture technology is successfully operating at pilot and commercial scales in the United States and around the world. The global carbon capture and storage market is predicted to nearly double between 2016 and 2022. The ability to sell or use CO_2 to make useful products makes the economics of these projects more appealing, and CO_2 is already considered a valuable commodity for certain uses. Today, CO_2 is used in enhanced oil recovery (EOR) and R&D is underway to produce stronger and lower-cost cement. Further, when coupled with sustainably produced hydrogen, synthetic fuels, chemicals, and plastics can be manufactured directly from captured CO_2. With these envisioned applications, the market for CO_2 is expected to grow. The recent expansion of the 45Q Carbon Capture Incentive, a federal tax credit for carbon capture and utilization projects in the United States, is expected to unleash $1 billion in investment over the next six years—a lucrative technology market where America can get ahead.

Further Reading on CDR and CCUS:

1. National Academy of Science. *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda*. 2018. https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda
2. National Academy of Science. *Gaseous Carbon Waste Streams Utilization: Status and Research Needs*. 2018. https://www.nap.edu/catalog/25232/gaseous-carbon-waste-streams-utilization-status-and-research-needs
3. United Nations Intergovernmental Panel on Climate Change (IPCC). *Special Report: Global Warming of 1.5C*. 2018. https://www.ipcc.ch/sr15/
4. Carbon180. *A Review of Global and U.S. Total Available Markets for Carbontech.* 2018. https://carbon180.org/carbontech-labs-reports

Energy Innovation Act; the ARPA-E Reauthorization Act; the Promoting Small Business Innovation through Partnerships with National Labs Act; the Fossil Energy R&D Act; the USE IT Act and others.

There are reasonable steps that Congress can take to build upon these early steps to establish an energy innovation portfolio that matches the scale of the climate challenge while opening new markets and protecting national security. Since 2010, the American Energy Innovation Council (AEIC), convened by BPC, argued that federal investment in energy innovation must be tripled from slightly more than $5 billion in 2010 to $16 billion by 2015. We have yet to hit that goal. A recent report from the AEIC, *Energy Innovation: Fueling America's Economic Engine*, proposes several other near-term steps to enhance federal innovation investment:

1. Fund DOE's Advanced Research Projects Agency-Energy (ARPA-E) at $1 billion per year. At a minimum, ARPA-E should receive $400 million per year in fiscal year (FY) 2020, a $34 million increase over FY 2019, which would allow one additional high-impact R&D program to be released by ARPA-E in that year.
2. Support and expand new and innovative institutional arrangements, such as energy innovation hubs, energy frontier research centers, the Manufacturing USA program, and the Energy Materials Network.
3. Make DOE work more efficiently —along the ARPA-E model where appropriate.
4. Establish a New Energy Challenge Program for high-impact pilot projects.
5. Establish regionally centered innovation programs.
6. Have the federal government support creative efforts to incentivize private-sector investment in energy R&D.

In addition to supporting innovation through R&D funding, Congress must also consider technology-neutral, performance-based policies that incentivize the deployment of all non-carbon energy sources. Legislation, such as the Clean Energy for America Act, that would provide equitable tax incentives for all non-carbon technologies is a step in the right direction. Even more significant would be an ambitious Zero Carbon Electricity Standard that in addition to supporting nuclear power, carbon capture, energy efficiency, and renewable wind and solar would include provisions to support innovative energy technologies and other first movers through benefit multipliers that sunset as an industry matures. While any mandate will be contentious, a consistent federal requirement for zero-carbon power would be far more effective than the current panoply of state renewable power mandates. But, lessons can be drawn from the states. Efforts in California, New Jersey, and New York to expand requirements to count all zero-carbon production offer a model for federal consideration.

We know that a mix of state and federal policies can be effective. The combination of incentives in PURPA, federal tax credits for wind and solar, procurement goals/mandates, Recovery Act provisions, and state renewable portfolio standards and tax incentives have spurred the private investment that has led to the boom in wind and solar deployment. Having achieved this success, Congress must now increase its ambition to support a competition among all sources of non-carbon energy production.

I would like to close by raising a difficult question for which I have no good answer. Will the United States continue to build and commercialize first-generation breakthrough energy technologies? While American innovation is alive and well in the software technology sector, where ingenuity and $1 million can create a new and valuable service, the energy technology sector innovates in billion dollar commitments to projects that take a decade or more from conception to completion. The financial and political risks inherent in these critical achievements are prohibitive for the private sector. We cannot accept a future in which all energy breakthroughs are commercialized in China or other centrally planned economies. The loan guarantee programs have been successful to a point, but we must entertain new approaches that share risks among the public and private sectors to enable our great nation to achieve great things.

Conclusion

Federal energy innovation investments are providing valuable economic and environmental benefits despite the lack of a meaningful consensus about program goals or future direction. There is broad support in Congress for energy security and economic competitiveness, but absent an informed, bipartisan consensus in favor of a real technology solution to a real climate problem, U.S. innovation efforts will fall far short. While success here may not capture the imagination of landing on the moon, the stakes are far greater. This Committee is the single best place in the U.S. government to rebuild an evidence-based approach to the climate and energy challenge. BPC stands ready to assist the Committee in any way we can.

Appendix

Further reading on the imperative for a technologically inclusive innovation agenda.

American Energy Innovation Council Reports

American Energy Innovation Council. “The Business Plan.” 2010. http://americanenergyinnovation.org/2010/06/the-business-plan-2010/

American Energy Innovation Council. “Catalyzing Ingenuity.” 2011. http://americanenergyinnovation.org/2011/09/catalyzing-ingenuity/

American Energy Innovation Council. “Restoring American Energy Innovation Leadership: Report Card, Challenges, and Opportunities.” 2015. http://americanenergyinnovation.org/2015/02/restoring-american-energy-innovation-leadership-report-card-challenges-and-opportunities/

American Energy Innovation Council. “The Power of Innovation: Inventing the Future.” 2017. http://americanenergyinnovation.org/2017/06/the-power-of-innovation-inventing-the-future/

American Energy Innovation Council. “Energy Innovation: Fueling America’s Economic Engine.” 2018. http://americanenergyinnovation.org/2018/11/energy-innovation-fueling-americas-economic-engine/

Importance of Firm Zero-Carbon Energy and Innovation

Jenkins, Jesse D., Max Luke, and Samuel Thernstrom. "Getting to Zero Carbon Emissions in the Electric Power Sector." *Joule* 2.12 (2018): 2498-2510. Available at: https://www.cell.com/action/showPdf?pii=S2542-4351%2818%2930562-2

Article summarizes forty recent studies addressing alternative pathways to deep decarbonization of power grids and concludes that the weight of the studies points to the conclusion that a diverse portfolio of zero carbon power options, including especially firm zero carbon energy, increases the chances of affordably meeting deep emission reduction targets.

Sepulveda, Nestor A., et al. "The role of firm low-carbon electricity resources in deep decarbonization of power generation." *Joule* 2.11 (2018): 2403-2420. Available at:

https://www.sciencedirect.com/science/article/pii/S2542435118303866

Article investigates the role of firm low-carbon resources in decarbonizing power generation in combination with renewable resources, electricity storage, demand response and long-distance transmission.

Intergovernmental Panel on Climate Change, "Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments" (2018) Available at: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

Scenarios for meeting 1.5 degree C target involved substantial increase in nuclear energy and carbon capture and storage as well as renewable energy.

Davis, Steven J., et al. "Net-zero emissions energy systems." *Science* 360.6396 (2018). Available at: https://energyinnovation.org/wp-content/uploads/2018/07/Davis-et-al_Science2018_net-zero-emissions-energy-with-Suppl.pdf

Examines challenge of decarbonizing some challenging energy services and industrial processes—such as long-distance freight transport, air travel, highly reliable electricity, and steel and cement manufacturing— concluding that "a range of existing technologies could meet future demands for these services and processes without net addition of CO_2 to the atmosphere, but their use may depend on a combination of cost reductions via research and innovation, as well as coordinated deployment and integration of operations across currently discrete energy industries."