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Testimony for the Record
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Hearing on U.S. Leadership in Nuclear Energy
and S. 903, the Nuclear Energy Leadership Act
Committee on Energy and Natural Resources
United States Senate
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Chairman Murkowski, Ranking Member Manchin, and distinguished members of this committee, thank you for holding this hearing, and for giving me the opportunity to testify.

I am honored to provide input. My name is Ashley Finan, and I am Executive Director of the Nuclear Innovation Alliance (NIA). The NIA is a non-profit think tank that does research, analysis, and stakeholder engagement dedicated to supporting entrepreneurialism, accelerated innovation, and the commercialization of advanced nuclear energy to address global energy needs.

In the United States and elsewhere, dozens of innovative start-up and established companies are pioneering advanced nuclear designs that offer opportunities for increased safety and affordability, the incorporation of safeguards and security by design, and an overall reduction in nuclear waste. These designs can revolutionize the nuclear industry and revitalize U.S. exports with products that take advantage of the latest manufacturing and computing technology, are competitive in markets across the globe, and exceed the expectations of customers and the public.

Innovators are focusing on better meeting the needs of traditional markets through reduced costs, as well as meeting the needs of the markets of tomorrow, including:

- Microgrids that power remote communities
- Secure and resilient power for critical commercial and defense infrastructure or emergency power supply
- Small grids in growing and emerging economies
- Grids with high penetration of renewable energy technologies, and
- Hybrid energy systems that can contribute to decarbonization of non-electric energy.

New nuclear energy technologies range in size from 1 megawatt or less to over 1 gigawatt, spanning at least three orders of magnitude. Some are designed to be transportable and many to be factory-manufactured. All are designed to be more resilient and more agile in operation than today's plants, with increased capacities for ramping and decreased footprints. Many build upon research, development, and demonstration (RD&D) performed in the first decade of civilian nuclear energy development by applying subsequent decades of technological progress in materials science, computing, mechanical engineering, and other fields that have been slow to percolate into existing nuclear energy systems. Our national labs have long played a key role in nuclear R&D and are working to accelerate the uptake of new technologies in nuclear energy. The private-sector-driven innovation that we are seeing today is sorely needed and long overdue, and it presents the United States with an opportunity to regain leadership in nuclear energy technology.

I will focus my testimony on three main topics:

- First, why US nuclear leadership is important
- Second, why and how it is possible to restore it, and
- Third, how the Nuclear Energy Leadership Act contributes to that process.

U.S. Nuclear Energy Leadership Has Geopolitical and Environmental Benefits

U.S. nuclear energy leadership has important implications for both geopolitics and for the environment;[1] I discuss each in turn below.

Nuclear Energy Geopolitics

Geopolitics scholars have asserted that energy relationships will have immense impact on future political relations.[2] In the present "era of great power competition," RAND corporation has identified international energy policy as a key means of competing through economic statecraft.[3] RAND calls out the specific examples of Russian energy diplomacy toward Europe (which includes nuclear fuel and technology supply) and the Chinese Belt and Road Initiative (which includes nuclear energy exports).

It is evident to most Americans that oil and natural gas play important roles in our foreign policy; there is regular media coverage of the topic. Recently, unconventional oil and gas and the increased mobility of natural gas with new technologies have led to sweeping changes in global markets. The U.S. has become a net exporter of natural gas, and LNG's competitiveness is loosening the grip of some countries that control key pipelines. Experts and economists have emphasized that natural gas and oil are becoming less effective as political tools and more

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[1] This is not an exhaustive treatment of potential benefits; U.S. nuclear energy leadership may have benefits for the economy, electric power reliability, and perhaps other areas, but my focus in this testimony is on geopolitical and environmental benefits.

[2] See, for example, remarks of Dr. Rachel Bronson, President and CEO of the Bulletin of the Atomic Scientists at event: "The Geopolitics of Nuclear Energy: The Role of U.S. Government and Industry, Past and Present" March 25, 2019. Recording available at: https://www.youtube.com/watch?v=dMe0_zaFXWk&feature=youtu.be; and O'Sullivan, Megan L. *Windfall: How the new energy abundance upends global politics and strengthens America's power.* Simon & Schuster, 2017.

[3] Mazarr, Michael J., Jonathan S. Blake, Abigail Casey, Tim McDonald, Stephanie Pezard, and Michael Spirtas, "Understanding the Emerging Era of International Competition: Theoretical and Historical Perspectives." Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2726.html.

driven by markets.[4] They have also stressed that a transition to a more sustainable energy supply could generate major changes in global politics and relationships. Politics of pipelines could be replaced by politics of super-grids. The place of oil could be taken by lithium or cobalt, materials used in batteries, for example.[5]

Nuclear energy is already playing a role in energy geopolitics, and we are at the option stage of exercising valuable opportunities for the United States. Nuclear energy supplier/customer relationships are materially different from those relationships in oil and gas. Nuclear is characterized by technological dependence that is much more enduring.[6] According to Jessica Jewell and coauthors in a paper in the May 2019 issue of Energy Policy, nuclear plants in Hungary, Slovakia, Bulgaria, and the Czech Republic can only be fueled by a single Russian company.[7] As Russia expands its sales that dynamic will grow. Similarly, the expertise involved in operating and maintaining key components of a particular design of nuclear power plant is often housed within a few companies.

Despite the relative loosening of oil and gas markets, most people would still ascribe a degree of associated political power to the major suppliers. Here are some facts and figures: According to Dr. Jewell's paper, 18 countries out of nearly 200 account for about 90% of global oil and gas supply, with Saudi Arabia supplying 19% of internationally traded crude oil, and Russia supplying 20% of internationally traded gas as of 2016. By comparison, for nuclear technologies, just 6 countries account for 90% of supply, and Russia is the supplier in 46% of nuclear technology agreements. (France is the supplier in 13% and the U.S. and China each 10%.) This is not a market characterized by a straightforward bidding process that is driven solely by energy prices. There are a handful of suppliers, and in most cases their governments are parties to their deals.

Russia and China are both thinking and acting strategically. They both have the capacity and the will to bundle generous financing with nuclear deals. The United States doesn't operate in the same way, though we have some support mechanisms. Where we excel most is in innovation. We have the best innovators, labs, and private investors in the space, and moving that innovation to commercialization provides us with a real opportunity to compete, if we can complement it with supportive government policy.

The discussion above focused on the energy supply aspect of nuclear energy trade. Other interactions involve nuclear safety, security, and nonproliferation, all issues of immense importance to the United States and the world. In the past, the strong presence of the United

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[4] O'Sullivan, Megan L. *Windfall: How the new energy abundance upends global politics and strengthens America's power.* Simon & Schuster, 2017.
[5] Ibid.
[6] Nuclear power plant trade relationships are often referred to as "100-year relationships," when planning, construction, 60-years of operation, and decommissioning are considered.
[7] Jewell, J., Vetier, M., and Garcia-Cabrera, D. "The international technological nuclear cooperation landscape: A new dataset and network analysis." *Energy Policy 128* (2019) 838-852. https://doi.org/10.1016/j.enpol.2018.12.024

States in nuclear energy export markets enabled the United States to strongly impact global safety and nonproliferation standards and behaviors.[8] The status of the U.S. Nuclear Regulatory Commission as a model of excellence in nuclear safety regulation has led many countries to seek U.S. input on their regulatory programs in the past.[9] Today, many nations are showing an interest in developing civilian nuclear power systems where they do not currently exist as a way to provide energy for a growing economy while reducing emissions. The U.S. will have weak leverage in influencing their nonproliferation, safety, and security standards and practices if we are not in a position to supply the energy technologies that these countries seek to acquire.[10] U.S. conditions on the supply of these technologies through 123 Agreements go well beyond the provisions in the Treaty on the Non-Proliferation of Nuclear Weapons, and represent some of the strongest nonproliferation conditions that exist. They include nine specific legally-binding commitments, for example: that all transferred material is kept under safeguards in perpetuity; that nothing transferred is used for a military purpose; that the United States has the right to recall any transferred material or equipment or special nuclear material produced through their use in the event of violation of IAEA safeguards or detonation of a nuclear explosive; and that material cannot be re-transferred without prior U.S. consent.[11,12] In addition to these benefits for geopolitics and global nonproliferation policy, experts argue that U.S. commercial nuclear power supports the U.S. naval propulsion program through the fuel cycle, a vendor supply chain, and the human resource pipeline.[13]

A declining U.S. nuclear energy industry constrains U.S. influence in key global relationships and standards, but the emergence of innovative, best-in-the-world technology provides the option to recapture a leadership role.

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[8] *Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative*. The CSIS Commission on Nuclear Energy Policy in the United States. Center for Strategic and International Studies, June 2013. *https://www.csis.org/analysis/restoring-us-leadership-nuclear-energy*

[9] Remarks of the Honorable William C. Ostendorff, U.S. Naval Academy Professor and former NRC Commissioner, at event: "The Geopolitics of Nuclear Energy: The Role of U.S. Government and Industry, Past and Present" March 25, 2019. Recording available at: https://www.youtube.com/watch?v=dMe0_zaFXWk&feature=youtu.be

[10] *Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative*. The CSIS Commission on Nuclear Energy Policy in the United States. Center for Strategic and International Studies, June 2013. *https://www.csis.org/analysis/restoring-us-leadership-nuclear-energy*

[11] Remarks of Ambassador Laura S. H. Holgate (ret.), at event: "The Geopolitics of Nuclear Energy: The Role of U.S. Government and Industry, Past and Present" March 25, 2019. Recording available at: https://www.youtube.com/watch?v=dMe0_zaFXWk&feature=youtu.be

[12] Atomic Energy Act of 1954 [As Amended Through P.L. 115-439, Enacted January 14, 2019], https://legcounsel.house.gov/Comps/Atomic%20Energy%20Act%20Of%201954.pdf

[13] Michael Wallace, Amy Roma, Sachin Desai, *Back from the Brink: A Threatened Nuclear Energy Industry Compromises National Security*, Center for Strategic and International Studies (July 2018), *available at* https://www.csis.org/analysis/back-brink-threatened-nuclear-energy-industry-compromises-national-security.

Environmental Benefits of Nuclear Energy

As an energy source that does not emit greenhouse gases or other air pollutants during operation, nuclear energy has positive impacts on clean air. China's pursuit of increased nuclear energy is in part a strategy to reduce air pollution, and a NASA study found that air pollution reduction from nuclear energy prevented about 1.8 million deaths between 1971 and 2009 and has the potential to prevent 4 to 7 million more air pollution deaths by 2050.[14]

On a global scale, climate change has the potential to harm vulnerable populations and ecosystems, and some analyses suggest these effects are already being felt via increased intensity of storms, drought, and wildfires, which may be more likely due to climate change and are expected to increase with further warming.[15,16] Under some scenarios, climate change is expected to bring humanitarian and ecological disruption and displacement on a scale that humankind has never experienced. The World Bank report *Groundswell: Preparing for Internal Climate Migration* projects that on our current path, over 143 million people in Sub-Saharan Africa, South Asia, and Latin America could be compelled to migrate within their countries by 2050.[17] The *Fourth National Climate Assessment* estimates that if climate change continues at its current pace, the annual costs to the U.S. economy could reach hundreds of billions of dollars by the end of this century.[18] Climate change is also a threat multiplier that can be expected to increase conflict in areas predisposed to it.[19,20]

The *2014 Quadrennial Defense Review* states:

> The pressures caused by climate change will influence resource competition while placing additional burdens on economies, societies, and governance institutions around the world. These effects are threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions – conditions that can enable terrorist activity and other forms of violence.[21]

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[14] Karecha, P.A. and Hansen, J.E. "Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power" *Environ. Sci. Tech. 47*, 4889-4895, 2013. dx.doi.org/10.1021/es3051197

[15] Hsiang, S. et al., *America Climate Prospectus: Economic Risks in the United States*. Rhodium Group, LLC. October 2014 (version 1.2). https://www.impactlab.org/research/american-climate-prospectus/

[16] Emanuel, K. (2007). Environmental Factors Affecting Tropical Cyclone Power Dissipation. Journal of Climate, 20(22), 5497–5509. doi:10.1175/2007JCLI1571.1

[17] Rigaud, Kanta Kumari; de Sherbinin, Alex; Jones, Bryan; Bergmann, Jonas; Clement, Viviane; Ober, Kayly; Schewe, Jacob; Adamo, Susana; McCusker, Brent; Heuser, Silke; Midgley, Amelia. 2018. *Groundswell : Preparing for Internal Climate Migration*. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/29461 License: CC BY 3.0 IGO."

[18] U.S. Global Change Research Program. Fourth National Climate Assessment, Volume II. November 2018. doi: 10.7930/NCA4.2018. Available online at: https://www.globalchange.gov/nca4

[19] Feitelson, E., and A. Tubi, 2017: A main driver or an intermediate variable? Climate change, water and security in the Middle East. Global Environmental Change, 44, 39–48. doi:10.1016/j.gloenvcha.2017.03.001.

[20] Schleussner, C.-F., J. F. Donges, R. V. Donner, and H. J. Schellnhuber, 2016: Armed-conflict risks enhanced by climate-related disasters in ethnically fractionalized countries. Proceedings of the National Academy of Sciences of the United States of America, 113 (33), 9216–9221. doi:10.1073/pnas.1601611113

[21] *Quadrennial Defense Review 2014.* United States Department of Defense, 2014. Available online at: https://dod.defense.gov/News/Special-Reports/QDR/

To mitigate the consequences, we need to decarbonize global economies, and that requires rapidly decarbonizing energy supply in the power grid (where nuclear has a proven track record) and beyond, where nuclear energy has strong potential to contribute.

In a review of 40 "deep decarbonization" studies published since 2014, Jesse Jenkins, Max Luke, and Samuel Thernstrom distilled some key insights:

- Affordable electric power can take on outsized importance in the effort to decarbonize because it can help to decarbonize other challenging sectors through increased electrification.
- Variable renewable energy sources (e.g. wind and solar) can drive decarbonization with modest system costs up to levels of roughly 50% of electricity supply, but approaching 80% or 100%, system costs accelerate rapidly, driven by low utilization, storage requirements, massive increases in transmission, and other factors.
- The most affordable pathways to deep decarbonization consistently include firm low-carbon resources (e.g. nuclear energy or fossil with CCS).
- A balanced portfolio of electricity sources increases our odds of achieving affordable decarbonization.[22]

Sepulveda, et al., in a paper in *Joule* in 2018 further describe "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation."[23] The authors divide low-carbon electric power sources into three categories:

1. "Fuel-saving" variable renewable energy sources like wind, solar, and some hydro;
2. "Fast-burst" balancing sources including batteries, demand-response, and similar sources; and
3. "Firm" low-carbon resources like nuclear energy, fossil power with CCS, geothermal power, biomass/fuels, and some hydro.

Using a power system model, the authors directly compare the cost of decarbonization systems that include all three sources with those that ex-ante exclude firm low-carbon resources (instead including only fuel-saving and fast-burst resources). The authors systematically evaluate 912 scenarios that account for various technology costs, decarbonization targets, geographical and policy constraints, and other factors. The figure below shows a summary of results for a "Northern" region similar to New England.

[22] Jenkins, Luke & Thernstrom (2018), "Getting to zero: insights from recent literature on the electricity decarbonization challenge," *Joule 2*, 2487-2510, December 19, 2018.
[23] Sepulveda et al., The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation, *Joule 2*, 2403-2420, November 21, 2018. https://doi.org/10.1016/j.joule.2018.08.006

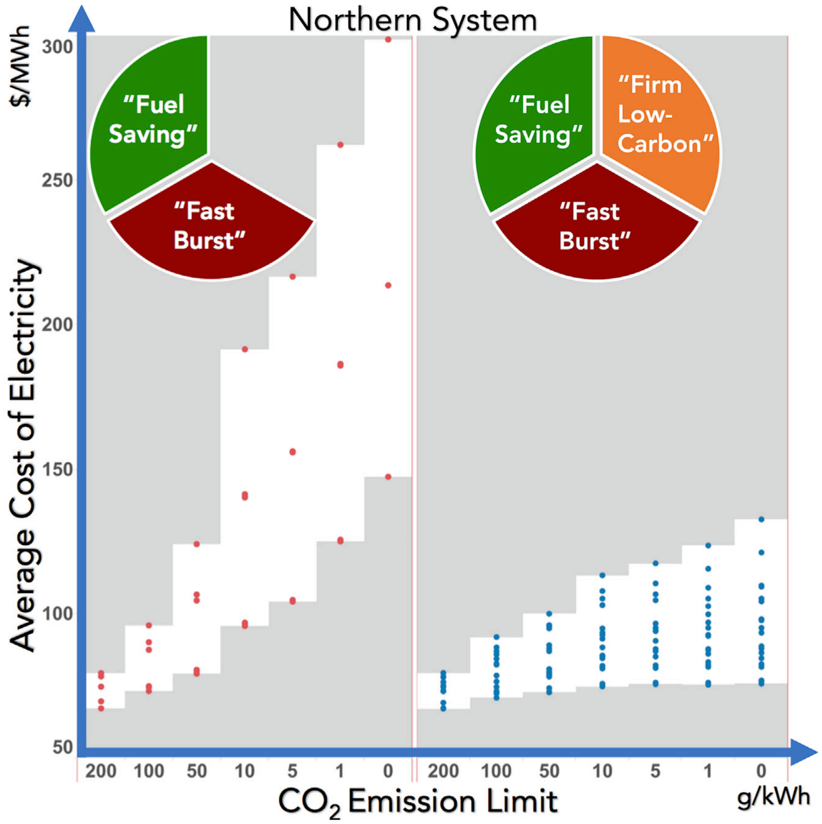

Figure 1: Average Cost of Electricity under Various Technology Assumptions and CO_2 Emission Limits for the Northern System (a) with a decarbonization policy that ex-ante excludes firm low-carbon resources on the left and (b) with a decarbonization policy that includes firm low-carbon resources on the right.

Source: Reprinted with permission from Sepulveda et al., "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation," *Joule* (2018), https://doi.org/10.1016/j.joule.2018.08.006

The figure illustrates that especially at deep decarbonization levels, the presence of firm low-carbon resources in the power mix is demonstrably responsible for keeping electricity costs down.[24] While there are other candidates for that role, such as fossil fuels with carbon capture, and "firm renewables" such as advanced geothermal, nuclear energy has a proven track record of quickly scaling and should continue to be part of the portfolio.

Several retrospective analyses of nuclear deployment rates have shown that nuclear power has scaled as fast as renewables, or faster, suggesting that both nuclear and renewable technologies could be scaled up quickly to address climate change under the right market and

[24] For reference, according to Sepulveda et al., in 2005 the U.S. CO_2 emissions rate from power generation was 595.8 g/kWh.

siting conditions.[25] Figure 2, below, from a publication by Amory Lovins, shows how quickly carbon-free energy has been added to the electric power mix in countries with major expansions of nuclear, solar, wind, and other renewable energy. It is notable that, in the case of France, an industrialized nation's power grid was 80% decarbonized in less than two decades via scale-up of nuclear energy. All energy technologies face constraints on siting, scalability, or performance due to geophysical, climate, weather, and societal factors – another reality that supports the use of a diverse resource mix.

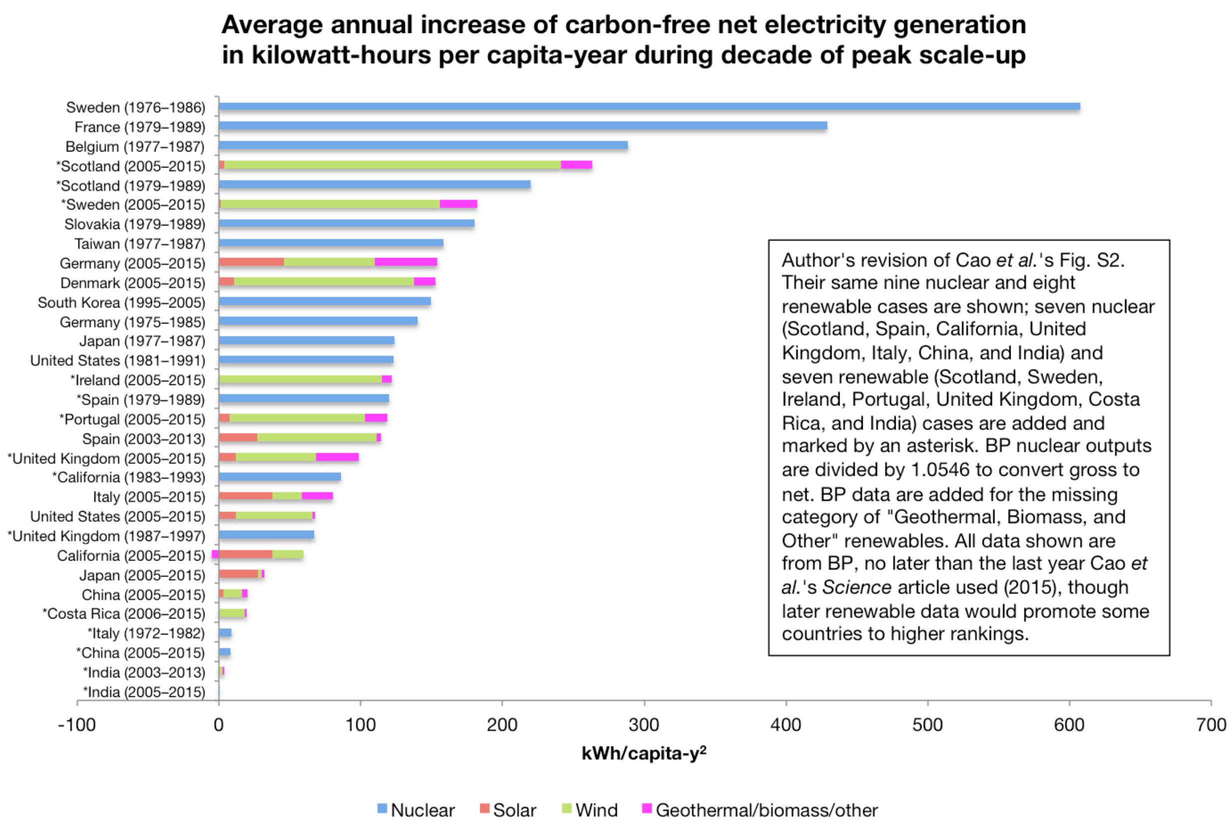

Figure 2: Average annual increase of carbon-free net electricity generation in kilowatt-hours per capita-year during decade of peak scale-up.

Source: Reprinted with permission from Lovins, A. "Corrigendum to "Relative deployment rates of renewable and nuclear power: A cautionary tale of two metrics," [Energy Res. Soc. Sci. 38 (2018) 188-192]" Energy Research and Social Science *46* pages 381-383. December 2018;

As these studies and others have shown, deep decarbonization can be more feasible and more affordable when nuclear energy is part of the power mix. [26] At the same time, there are serious

[25] See, for example: Lovins, A. "Corrigendum to "Relative deployment rates of renewable and nuclear power: A cautionary tale of two metrics," [Energy Res. Soc. Sci. 38 (2018) 188-192]" Energy Research and Social Science *46* pages 381-383, December 2018.

[26] See, for example: *The Future of Nuclear Energy in a Carbon-Constrained World*, MIT Energy Initiative, Massachusetts Institute of Technology, 2018. Available online at: http://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/

questions about whether nuclear energy can possibly fill the role that these models suggest we need it to, "in the absence of a dramatic change in the policy environment."[27]

Existing nuclear power plants are struggling to compete in an era of low-cost natural gas, but the shutdown of existing nuclear power plants is a step backward in any quest to reduce carbon emissions.

Advanced nuclear energy provides the United States with a compelling but perishable opportunity to develop a low-carbon technology that will help to provide the world with an affordable, scalable tool to address the global need for expanded access to clean energy. One could argue that the United States has not only the opportunity, but also the responsibility to take action.

But many are doubtful about the ability to develop that technology in the needed timeframe.[28]

History Counsels Us To Be More Hopeful

Make no mistake; commercializing nuclear energy technology to address pollution and regain a leadership role will be hard. <u>We have not done this recently, but we have done this before.</u> The Atomic Energy Commission (AEC), a predecessor to the DOE, was responsible for the early development of nuclear power in the United States and was successful in both shepherding the commercialization of nuclear power plants now operating, and demonstrating a handful of other designs, several of which are revisited in the companies pursuing nuclear energy innovation today. An in-depth analysis by researchers at the Electric Power Research Institute (EPRI) and Vanderbilt University provides some important insights.[29] (This report is referred to as "the EPRI report" in following indications.)

The EPRI report provides an in-depth review of the history of technology-specific programs in reactor commercialization in the United States (developing pressurized water and boiling water reactors), United Kingdom (developing the gas-cooled reactor), and Canada (developing the pressurized heavy water reactor). The findings are encouraging for the potential for nuclear power commercialization to proceed rapidly, though with the caveat that policy conditions were somewhat different at the time given Cold War competition, defense-related complementary R&D, and a clear government mandate.[30]

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[27] M. Granger Morgan, Ahmed Abdulla, Michael J. Ford, and Michael Rath, "US nuclear power: The vanishing low-carbon wedge." PNAS July 10, 2018 115 (28) 7184-7189. https://doi.org/10.1073/pnas.1804655115

[28] See, for example: Morgan et al. in footnote 27, above, and Lyman, Edwin, "Testimony before the U.S. Senate Subcommittee on Clean Air and Nuclear Safety on 'Enabling Advanced Reactors and a Legislative Hearing on S.2795, The Nuclear Energy Innovation and Modernization Act'" 4/21/16.

[29] *Program on Technology Innovation: Government and Industry Roles in the Research, Development, Demonstration, and Deployment of Commercial Nuclear Reactors: Historical Review and Analysis.* EPRI, Palo Alto, CA: 2017. 3002010478.

[30] Ibid.

In the UK, only 3 years passed between the establishment of the civilian nuclear power program and the startup of the first commercial (prototype) nuclear power plant (Calder Hall-1; 50 MWe).[31] After several more reactors of increasing size, the first two Hinkley Point reactors started operation in 1965, just 12 years after the program started. The EPRI report characterizes Hinkley Point-1 (235 MWe) as the first fully commercial reactor and thus evaluates the "time to commercialization" of the UK gas-cooled reactor as 12 years. The EPRI report similarly evaluates the "time to commercialization" for the U.S. boiling water reactor as 13 years, for the U.S. pressurized water reactor as 15 years, and for Canada's pressurized heavy water reactor as 16 years.

Through 1962 in the United States, approximately $11 Billion (in 2017 USD) were invested in civilian nuclear power research, development, and demonstration, with 58% provided by the Atomic Energy Commission and 42% provided by industry.[32] The signature demonstration program of the AEC was the Cooperative Power Reactor Demonstration Program (CPRDP), which used a variety of support mechanisms and cost-sharing arrangements for 11 demonstration projects and 2 commercial scale reactors covering 8 technologies. The AEC provided support for construction costs, fuel leasing, fuel fabrication, R&D costs, decommissioning, and various other items. The CPRDP was funded at approximately $4.3 Billion (in 2017 USD) with 66% coming from industry and 34% from the AEC, but with the AEC share ranging from as little as 8% to as high as 86% from one project to the next.[33] At the same time, there were several projects built without any government cost-share.

The CPRDP was successful in demonstrating a wide variety of designs in a rapid manner with government-industry cost-sharing. But we have learned a lot since then and can do this even better and faster than we did at the inception of the industry. Specifically, we can more effectively harness the power of the market and private sector entrepreneurialism.

A forthcoming NIA report will suggest specific approaches for efficiently structuring a new program for advanced nuclear energy demonstration that would use insights from the NASA Commercial Orbital Transportation Services (COTS) program to improve upon the CPRDP and the programs that followed it by more effectively harnessing private sector capital and capability.[34] I hope that this report will prove useful as DOE works to implement the program envisioned in the Nuclear Energy Leadership Act, if Congress should decide to pass and fund it.

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[31] Jensen, S.E. and Nonbol, E. "Description of the Magnox Type of Gas Cooled Reactor (MAGNOX)." Nordic Nuclear Safety Research, Denmark: 1998. Available online at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/30/052/30052480.pdf Accessed 4/18/19.

[32] *Program on Technology Innovation: Government and Industry Roles in the Research, Development, Demonstration, and Deployment of Commercial Nuclear Reactors: Historical Review and Analysis.* EPRI, Palo Alto, CA: 2017. 3002010478.

[33] Ibid.

[34] Bowen, M. *Enabling Nuclear Innovation: In Search of a SpaceX for Nuclear Energy.* Nuclear Innovation Alliance, 2019 (forthcoming).

Key recommendations from the forthcoming NIA report include:

1. DOE should seek one or more consultants with venture capital and/or start-up experience to advise it on the design and implementation of the advanced reactor demonstration program. DOE should also consult with NASA COTS program leadership and experts to gain further understanding of the success drivers in the program, as well as any potential improvements that NASA identified. DOE should identify any statutory restrictions that would prevent it from implementing an innovation-oriented public-private partnership modeled after the NASA COTS experience.

2. Congress should address any statutory restrictions that would prevent DOE from carrying out an innovation-oriented public-private partnership similar to the NASA COTS program. NASA's statutory authority came from the "other transaction" authority in the 1958 Space Act. DOE's authorities are derived from the Atomic Energy Act of 1954, the Energy Policy Act of 2005 (EPACT05), and other legislation. Congress should work with DOE to determine whether there are any statutory restrictions under existing law that would prevent it from implementing a program that is comparable to the NASA COTS program in structure. If DOE identifies any potential problems, Congress should provide any needed technical fixes to provide the authority to carry out a milestone-driven advanced reactor program. DOE should be permitted to institute reasonable intellectual property assurances and ease contracting and permitting for demonstrations on DOE sites.

3. Once any statutory restrictions are addressed, DOE should establish a phased advanced reactor development and demonstration program modelled on the NASA pay-for-milestones approach of partnering with private companies. This could provide a management approach that is more similar to the way venture capital firms manage their investments, and one that is more transparent, structured, and enduring for longer-term advanced reactor demonstration. DOE should consult with NASA regarding lessons learned from their partnership with SpaceX and other companies in the COTS program, including the partnerships that ultimately did not lead to successes. For example, it would be useful for DOE to better understand how NASA structured its initial funding opportunity announcement, how it went about selecting partners, how it confirmed that partners had met milestones (or not), and in the case where partners did not meet their milestones, how NASA went about ending partnerships with the private companies and re-competing the remaining amounts of money in their agreements.

4. Congress should amend Section 203 of the Energy Policy Act of 2005 to require the federal government to purchase higher percentages of clean energy. Specifically, Congress should set higher goals for federal facilities to procure all forms of low-emission power. For example, Congress could require federal facilities to procure at least 30 percent of their power from zero carbon sources by 2030 or half of their power from such sources by 2035. Alternately or in addition, Congress could consider amending 10 U.S.C. 2911 to establish similarly higher clean energy goals for DOD than currently exist for renewable energy technologies.

The CPRDP was pursued in an era of Cold War competition and urgency with a clear and bold government mandate. Some of today's urgency is reminiscent of those days. The United States has near-peer competitors working to establish global energy market and nuclear dominance, something that U.S. foreign policy and security policy developers should be mindful of. But layered on top of that now is the threat of global climate change which some studies suggest is already damaging vulnerable populations and ecosystems and will bring further impacts to society and the environment across the globe in the years to come.

To meet these challenges, the United States public and private sectors should redouble efforts to commercialize scalable, affordable, and exceptional nuclear power technology. We have done this before with the CPRDP, during an era of big ideas and bold action. We see private sector companies and entrepreneurs pursuing bold ideas, and we need to call upon government to join them and support them, with the same spirit of the Atoms for Peace era, but with the benefit of decades of advancement and experience both in government policy and in technology.

The Nuclear Energy Leadership Act Sets the Bold Goals We Need

The Nuclear Energy Leadership Act (NELA) calls for the demonstration of at least 2 advanced nuclear reactors by the end of 2025 and 2 to 5 more by the end of 2035. These are the types of ambitious goals that we need to inspire a national commitment and to achieve milestones that will help us address the great challenges we face as a nation and a globe.

These are goals that are **specific, measurable**, **difficult**, and **achievable**. They also incorporate a timeline. There is strong consensus in goal-setting theory that these are defining characteristics of effective goals.[35]

NELA backs these goals with key supporting policies:

Section 1 suggests the purpose of this bill: to restore U.S. leadership in nuclear energy. This is a goal that has value for the United States' geopolitical and economic interests as well as for global environmental, societal, and security interests.

Section 2 authorizes long-term federal power purchase agreements (PPAs), as NIA recommended in our "Leading on SMRs" report,[36] which enables the federal government to provide an early market for advanced reactors on a time horizon consistent with the capital recovery period of these long-lived assets.

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[35] See, for example: Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*, *57*(9), 705-717; O'Neil Jr., H.F., & Drillings, M. (Eds.). (1994). *Motivation: Theory and research*. Hillsdale, NJ: Lawrence Erlbaum Associates; and Fried, Y., & Slowik, L. H. (2004). Enriching goal-setting theory with time: An integrated approach. *Academy of Management Review, 29*(3), 404-422.

[36] Bowen, M. *Enabling Nuclear Innovation: Leading on SMRs*, Nuclear Innovation Alliance, 2017. Available online at: https://www.nuclearinnovationalliance.org/leadingonsmrs

Section 3 creates a pilot program for long-term power purchase agreements for nuclear power that can support early stage technologies, especially as they demonstrate valuable attributes beyond typical electric power supply. This is consistent with a recommendation in NIA's "Leading on SMRs" report and will help provide a "market pull" for new technology to complement the "technology push" policies of federally supported research, development, and demonstration.

Section 4, as described above, sets the top-level advanced reactor demonstration goals that motivate the focus and enthusiasm that are needed to achieve success.

This section could be improved by clarifying that the demonstration projects should be undertaken in partnership with the private sector. For example, instead of "The Secretary shall … complete not fewer than 2 advanced reactor demonstration projects by …," consider: "The Secretary shall … partner with the private sector to complete not fewer than 2 advanced reactor demonstration projects by…." And, instead of "The purpose of this section is to direct the Secretary… by demonstrating different advanced nuclear reactor technologies that could be used by the private sector to produce…," Consider: "The purpose of this section is to direct the Secretary… by partnering with the private sector to demonstrate different advanced nuclear reactor technologies that could be used by the private sector to produce…."

This section should also be improved by clarifying that an evaluation of candidate technologies for the demonstration projects by an external review should be required ONLY for those technologies seeking a significant federal cost-share for demonstration. During the CPRDP, there were important test and demonstration reactors constructed that were privately funded, with assistance from the AEC only in the leasing of nuclear fuel and perhaps earlier stage R&D. It is conceivable that the same could happen this time around, and it's important that the conditions in NELA that are intended to ensure responsible use of federal funds do not delay private efforts that do not directly use federal funds.

Section 5 directs DOE to develop a 10-year strategic plan that will support the goals established in Section 4. This is a critical action, as the lack of long-term planning has at times hampered DOE-NE's ability to achieve program goals.[37]

Section 6 directs DOE to construct a Versatile, Reactor-Based Fast Neutron Source. This is a research and development facility that is required to perform state-of-the-art R&D. It will be useful in the development and evolution of advanced nuclear energy, but also in the development of safeguards techniques and medical applications and in support of our nuclear

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[37] See for example: Abdulla A, Ford MJ, Morgan MG, Victor, D. (2017) "A retrospective analysis of funding and focus in US advanced fission innovation." *Environ. Res. Lett. 12* (2017) 084016; Ford MJ, Abdulla A, Morgan MG, Victor, D. (2017) "Expert assessments of the state of U.S. advanced fission innovation." *Energy Policy* 108 (2017) pp. 194–200; and Finan, Ashley E. *Energy System Transformation: An Evaluation of Innovation Requirements and Policy Options.* (Chapter 4) Thesis (Ph. D.) Massachusetts Institute of Technology, Dept. of Nuclear Science and Engineering, 2012. https://dspace.mit.edu/handle/1721.1/77059

navy and other security programs. It is important scientific infrastructure for which we currently rely on Russia and China under arrangements that are neither technically, nor commercially, nor politically optimal.

Section 7 provides for an initial supply of fuel for early advanced reactors, in the absence of a domestic fuel supply for an emerging technology. This is a function that DOE is well-positioned to fill, that the AEC filled in the last round of new technology demonstrations, and that is important to the success of the private efforts currently underway.

Section 8 establishes a University Nuclear Leadership Program that would support the development of researchers and other professionals who are trained to support an advanced reactor program. Existing university nuclear programs focus primarily on light-water reactors, with less emphasis on next generation technologies, so this program would provide needed diversification and workforce development.

Complementary Policies

To secure a leadership position in the global nuclear market, the U.S. needs to move its designs from development to demonstration and deployment. Passage of the Nuclear Energy Leadership Act will aid that effort in important and very substantial ways. Other actions will be required. Some examples of complementary policies that are not necessarily in the purview of this Committee or even of Congress include:

1. Adequate, consistent, and predictable funding for the demonstration program outlined in NELA;
2. An implementation plan for the demonstration program that incorporates lessons learned from past efforts and other efforts like the NASA COTS program;
3. An executive order putting in place a more aggressive federal Clean Energy Standard that includes nuclear;
4. Increased U.S. involvement in nuclear energy development in newcomer countries:
    a. Increased NRC international programs in international nuclear safety consultations; expanded role for NRC in exporting U.S. regulatory expertise
    b. Increased Department of State and Department of Energy international nuclear programs (energy and/or science), including DOE involvement in international licensing harmonization efforts
    c. Inclusion of advanced nuclear in U.S. IDFC (and the World Bank and similar development finance organizations)
    d. Statement of importance and full functioning of the U.S. Export-Import bank
    e. Strengthened coordination of TEAM USA with a nuclear energy position in the National Security Council;
5. Priorities at DOE-NE/NNSA:
    a. Improved treatment of intellectual property
    b. Continued improvements to ensure that laboratories are doing work that is complementary, not in competition with, industry

c. Expansion of work on advanced reactor nonproliferation and safeguards R&D

6. Regulatory Modernization
   a. Continued progress on NRC development of advanced reactor regulatory infrastructure; adequate funding for that work
   b. Efforts to make NEPA reviews of demonstration reactors more efficient.

Conclusion

Nuclear energy is a vital element in helping the world to avoid the worst impacts of climate change, and U.S. leadership in the field serves U.S. economic, environmental, and security interests. The Nuclear Energy Leadership Act sets bold targets and supportive policies for the revitalization of our nuclear R&D program and for the demonstration and deployment of the next generation of U.S. nuclear energy technologies.

Coupled with investment, private sector action, and related energy, export, and environmental policies, NELA's ambitious goals are necessary and achievable. The Nuclear Innovation Alliance supports the Nuclear Energy Leadership Act, applauds its co-sponsors for their initiative and ambition, and stands ready to assist in any way that would be helpful to the Committee.

Thank you for this opportunity to testify. I would be pleased to respond to any questions you might have, today or in the future.